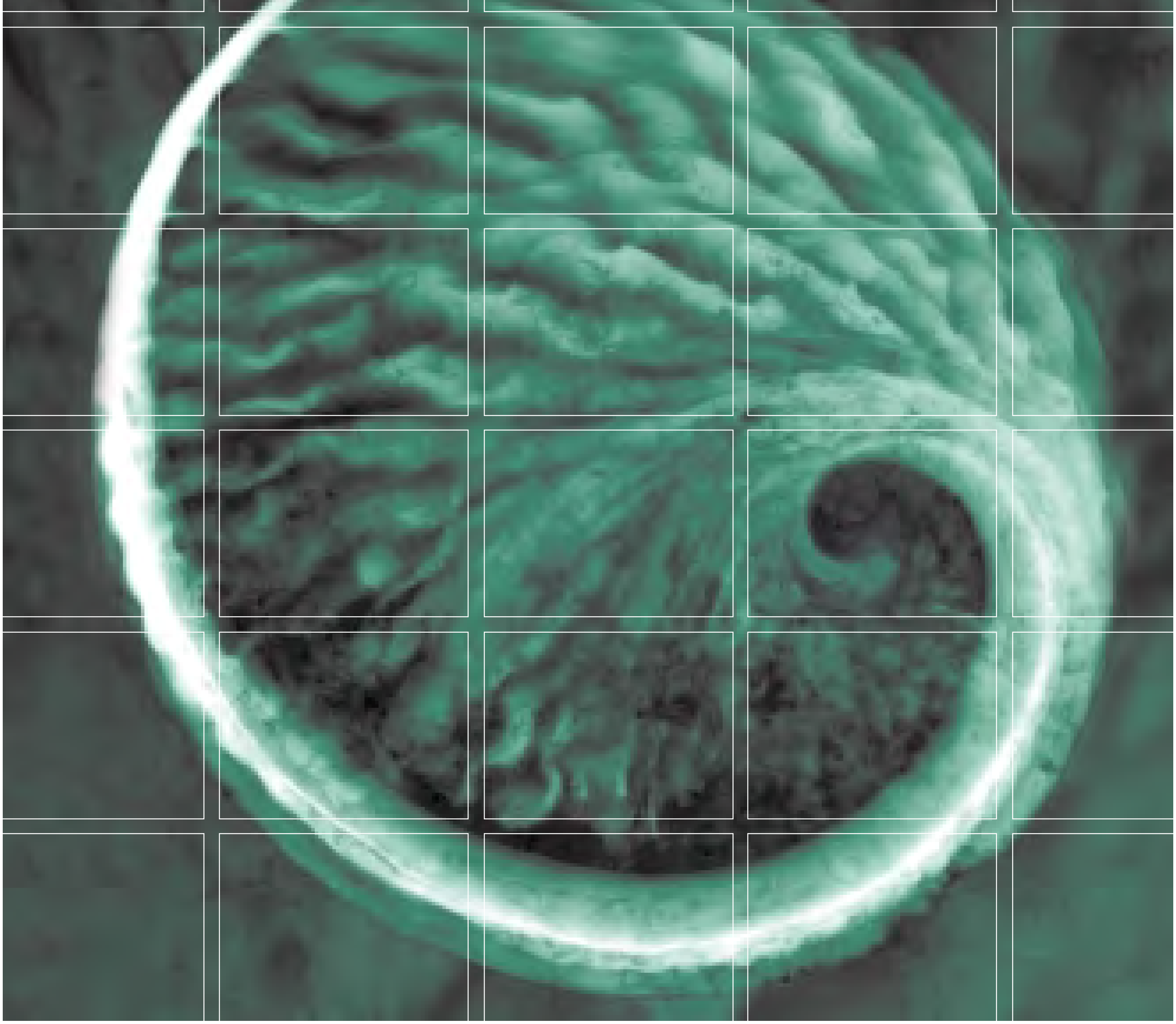

# Technical Impracticability Evaluation for Ground Water Restoration

**French Limited Superfund Site**
**French Limited Task Group**
**Crosby, Texas**

April 2, 2014

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French Limited Task Group

# Technical Impracticability Evaluation for Ground Water Restoration: *French Limited Superfund Site Crosby, Texas*

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## *EXECUTIVE SUMMARY*

Potentially responsible parties at the French Limited Superfund Site in Crosby, Texas (site) formed a task group in 1983 and in 1988 created FLTG, Inc. to investigate and remediate the site pursuant to a Consent Decree. The early efforts were successful in reaching the remedial action objectives (RAOs) established by the United States Environmental Protection Agency (EPA) for the source area. For ground water, an estimated 188 tons or more of constituent mass or more was removed by active and passive remediation. After review, EPA required that substantially greater mass be removed to achieve the RAOs. The list of remedial technologies that have been engineered and implemented to progress towards the RAOs include containment, pump and treat, permeability enhancement of low permeability zones, in-situ treatments, and monitored natural attenuation.

The estimated timeframe for possibly achieving the ground water RAOs is over 100 years using the above listed as well as additional engineered remedial strategies. This timeframe is not considered reasonable in the context established by the National Contingency Plan (NCP), which states *EPA expects to return ground water to their beneficial uses wherever possible, within a timeframe that is reasonable given the particular circumstances of the site* (NCP: 300.430(a)(1)(iii)(F)). It is technically impractical to achieve the RAOs within a shorter period of time given the complex geological and contaminant-related characteristics of the site. This document proposes a Technical Impracticability (TI) waiver for the ground water RAOs for the constituents of concern (COCs) of the site as a protective remedial strategy for managing the long-term protectiveness of the site.

A High-Resolution Site Characterization (HRSC) program was performed from 2011 to 2013 using in-situ characterization and sampling tools to confirm the viability of a new set of remedies proposed for ground water in the Supplemental Feasibility Study. The results confirmed the presence of a complex hydrogeological environment where the majority of the mass of the chlorinated volatile organic compounds (CVOCs) is contained within low-permeability zones. The proposed remedies are consistent with best practices for addressing VOC plumes, and are now deemed to be technically incapable of overcoming a slow, diffusion rate-limited constituent source within a reasonable length of time and cost.

This new information explains why the implementation of otherwise reliable and feasible technologies has not and is not likely to work within a reasonable period of time. EPA has published a *Summary of Technical Impracticability Waivers at National Priority List Sites*[1] that describes the justification for TI waivers that have been issued. Of the 91 TI waivers approved by EPA, the common circumstances of the sites included complex geology and non-aqueous phase liquid and other

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[1] USEPA, Solid Waste and Emergency Response, OSWER Directive 9230.2-24, August 2012.

complex chemical mixtures. These same circumstances exist at the site, having the following implications for ground water remediation:

- Complex geology is trapping COCs in heterogeneous, low permeability, interbedded fine-grained material (i.e., clay and silt), impairing the effectiveness of traditional as well as innovative ground water remedies to remove mass and achieve RAOs;
- Slow, continual releases from residual dense non-aqueous phase liquid (DNAPL) is making it impractical for remedial technologies to restore the ground water within a reasonable timeframe because it creates deep, large quantities of affected ground water; and
- EPA concluded that the in situ decay potential of a prevalent and concentrated COC, tertiary butyl alcohol, was limited thus requiring an engineered-based remedy to achieve RAOs.

The new investigation results were evaluated using a numerical plume diffusion model, which estimated the restoration timeframe to be greater than 100 years. The estimated cost to restore the site under this timeframe is at least $22 million and possibly exceeds $100 million. The added time and expense will not significantly improve the degree of protectiveness afforded by institutional controls and monitoring already in place at the site because the plume is naturally stable in a controlled area of the site.

A single TI Zone is proposed with an associated compliance boundary to include the area of affected ground water. A benefit of the complex geology is that the ground water flow rates are slow and the plumes are naturally stable. The existing Sheet Pile Wall, which also provides stability and containment of affected ground water within the former lagoon area, is an integral component of the TI Zone. The extent of COCs has been consistent since 1995, when a natural attenuation remedy was implemented. Outside the TI Zone, concentrations of residual levels of COCs that are below the RAOs are expected to continue to degrade. A monitor well network is proposed to demonstrate the performance of the TI waiver and success as an alternative, protective remedy for ground water at the site.

## 1.0 INTRODUCTION

For more than 30 years, the FLTG, Inc. (FLTG) has been investigating and implementing ground water remedies at the French Limited Superfund Site in Crosby, Texas (site) in an effort to achieve the remedial action objectives (RAOs) established for the site in March 1988. These remedies were selected as the most appropriate and applicable to address the residual concentrations of constituents of concern (COCs) in ground water and included a Sheet Pile Wall (SPW) around the former lagoon area, a pump and treatment system with enhanced bioremediation via in-situ injection, and most recently natural attenuation.

In each case, a review of the abundant ground water monitoring, site characterization, and mass removal data eventually lead to the same conclusion: currently available remedial technologies cannot reliably, reasonably, or feasibly attain the RAOs for ground water within a reasonable period of time. Ground water restoration is not feasible throughout the site[2]. The goal of this document is to present a case for utilizing a Technical Impracticability (TI) waiver as the most reasonable and appropriate means for addressing affected ground water at the site.

Active remedial operations were designed to address volatile organic compounds, semi-volatile organic compounds and inorganic compounds (metals) that were known to be present in the soil and ground water at the site above target levels. A Record of Decision (ROD) issued in March 1988 directed remedial efforts to achieve Applicable or Relevant and Appropriate Requirements (ARARs) for COCs in the two upper-most water-bearing units beneath the site (S1 and INT). The remedial objectives for ground water as presented in the 1988 ROD include:

- Objective 2: Reduce contaminants in the upper aquifer (S1)

  Criterion: USEPA Drinking Water Standards and/or ($10^{-4}$ to $10^{-7}$ cancer risk range) Human Health Criteria; and

- Objective 5: Reduce contamination in lower aquifer (INT)

  Criterion: USEPA Drinking Water Standards and/or ($10^{-4}$ to $10^{-7}$ cancer risk range) Human Health Criteria.

The components for addressing ground water ARARs in the ROD recommended alternative (Alternative 5) were:

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[2] In accordance with the Environmental Protection Agency's (EPA) *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (OSWER Directive 9234.2-25, September 1993), restoration refers to the reduction in constituent concentrations to levels required by Superfund under the Clean Water Act, defined as the remedial action objectives (RAOs) in the Record of Decision for the site. In many instances, the RAOs are the Maximum Contaminant Levels (MCLs) established for drinking water.

- Recover and treat contaminated ground water until modeling shows that a reduction in the concentration of volatile organics to a level which attains the $10^{-6}$ Human Health Criteria can be achieved through natural attenuation in ten years or less; and
- Monitor the upper and lower aquifers for a period of 30 years.

The ground water COCs identified at the site and their RAOs are listed in Table 1-1. The listed COCs are the focus of this evaluation. Following four years of aggressive remediation (from 1992 to 1995) and over 18 years of natural attenuation, the concentrations of COCs in several areas of the site remain above the RAOs and, in some instances, COC concentrations are showing no significant signs of decreasing anytime soon. For these reasons, a TI waiver is proposed for the ground water ARARs throughout the ground water plume areas.

## *1.1 TECHNICAL BASIS FOR THIS REPORT*

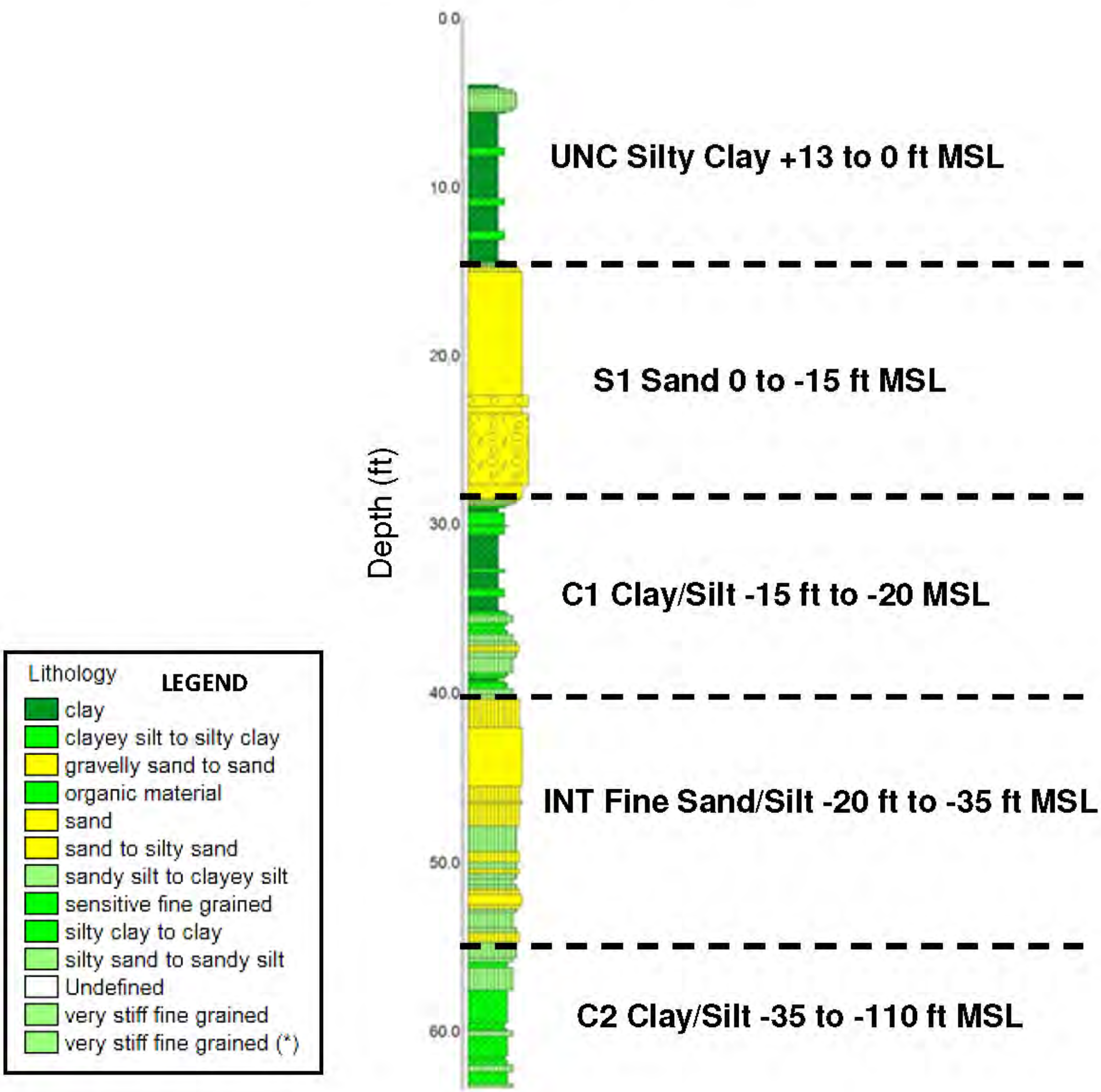
This report presents an engineering perspective[3] of the restoration potential of affected ground water at the site within a timeframe that is reasonable considering the particular circumstances of the site. Many factors are inhibiting the restoration of ground water at the site, the most prominent of which include:

- Complex hydrogeologic factors associated with the sedimentary deposits at the site trapped the COCs in a clay zone (C1) located beneath the uppermost water-bearing zone (S1) and in the reported lower water-bearing zone (INT), and allow them to continue to dissolve into ground water. Figure 1-1 below includes a conceptual geologic model of the site;
- The source of the most persistent COCs is a dense non-aqueous phase liquid (DNAPL) that was managed in the lagoon and addressed during the lagoon remedy. Residual DNAPL is held by capillary forces (chemical and physical processes) within the clay pores of the C1 clay zone in Central Plume Area and the residual DNAPL has not been observed to be mobile. A permeability enhancement treatment program was attempted in 1995 to mobilize the residual mass in the C1 and INT as part of the ground water remediation efforts. Although short-term yields improved, they were not sustained. The COCs in the residual DNAPL slowly dissolve and diffuse into ground water, shown as elevated COC concentrations in the C1 clay zone and sustained elevated concentrations of COCs in ground water in the S1 water-bearing zone immediately above it. Despite years of ground water treatment and natural attenuation processes, elevated concentrations are persistent and are not likely to decrease in a reasonable time frame; and

[3] The engineering perspective is defined as the approach that EPA uses "to evaluate the technical impracticability of attaining required ground-water cleanup levels and establishing alternative, protective remedial strategies where restoration is determined to be technically impracticable. Environmental Protection Agency's (EPA) *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (OSWER Directive 9234.2-25, September 1993), page 1.

- The technical capability of many remedial alternatives has been assessed through engineering feasibility studies and full-scale implementation over the last 20 years. The complex COC mixture has complicated the application of remedial technologies to the point that EPA and TCEQ have concluded that these measures have failed to achieve the remedial objectives, as document in the Third Five Year Review published in 2007.

Figure 1-1 Stratigraphic Summary



This report is intended to be a concise presentation of the relevant information for evaluating the site in accordance with the Environmental Protection Agency's (EPA) *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (OSWER Directive 9234.2-25, September 1993) and generally consistent with the Texas Commission for Environmental Quality's (TCEQ) Texas Risk Reduction Program (TRRP) guidelines for monitored natural attenuation (MNA) and plume management zones (RG-366/TRRP 28, RG-336/ TRRP-29 and RG-336/TRRP-33).

## *1.2 BACKGROUND INFORMATION*

The site (CERCLIS US EPA ID# TXD9805148) is located in northeast Harris County, two miles southwest of Crosby, Texas, near the San Jacinto River, at old US Highway 90 and Gulf Pump Road (Figure 1-2). The site is located within the floodplain of the San Jacinto River and in a floodway that is subject to a 1% annual chance flood (FEMA, 2006).

The site was used as a sand quarry in the 1950s and 1960s, which resulted in the formation of an approximately 8-acre sand pit. The site was permitted to accept industrial waste material from 1966 until 1971 and received an estimated 90 million gallons of chemical waste. The EPA placed the site on the National Priorities List (NPL) in 1982, and designated it for remedial action under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The French Limited Task Group (FLTG) was formed in 1983 to manage the remediation program on behalf of the Potentially Responsible Parties (PRPs). Remedial investigations and feasibility studies were completed between 1984 and 1986. EPA issued the Record of Decision (ROD) in 1988 (EPA, 1988) and the PRPs formed FLTG, Inc. to manage response actions. Figure 1-3 includes the site layout and the location of the ground water plumes.

## *1.3 REVISED SUPPLEMENTAL FEASIBILITY STUDY*

The first Supplemental Feasibility Study (SFS) was submitted to the EPA in 2006 and recommended Enhanced Biological Degradation/Phytoremediation with In-situ Treatment and MNA. EPA provided comments in 2007, stating that additional information was required to evaluate the predicted performance of the proposed remedy.

From 2007 to 2010, additional work was performed to strengthen the technical basis of the remedy evaluation process. The scope of this work was directed by EPA's comments, as well as FLTG's need to gain more information on site conditions and the trends of concentrations over time. A constructed wetlands treatability study was completed during 2007-2008 to evaluate this technology for treatment of site COCs.

The ground water remedy for the area outside of the Former Lagoon Area and SPW at the site was re-evaluated in the revised SFS dated September 29, 2010. The revised SFS incorporated findings of the new remedial studies and addressed EPA's comments to the 2006 version of the SFS. Appendix A of the revised SFS contains a summary of the EPA's comments on the 2006 SFS report and FLTG's responses and revisions incorporated into the current SFS report.

The current SFS considered the nature of the COCs, the geology and hydrogeology of the site, and the treatment experience from previous remediation to evaluate six remedial alternatives for affected ground water. Individual and comparative analyses were used to identify the relative advantages and disadvantages of each alternative and make a recommendation for a new ground water remedial approach. Of the alternatives considered, a possible combination of ground water extraction, constructed wetlands treatment, in-situ chemical oxidation (ISCO), and monitored natural attenuation (MNA) was considered the most feasible at that time. This approach was accepted by TCEQ and EPA under the Letter of Approval of Supplemental Feasibility Study for French Limited Superfund Site dated June 27, 2012.

With the EPA's concurrence on a new direction for the ground water remedy, a phased approach was initiated to gather information for the ultimate design of the remedy. The first step was to refine the conceptual model of the site, especially where concentrations of COCs remained the highest. Subsequent steps would align the remedial alternatives to where they were best suited for the site conditions.

A High-Resolution Site Characterization (HRSC) program was performed to provide additional data regarding the composition, concentrations and potential mobility of the COCs and to confirm the viability of the proposed remedy of the site. As discussed in Section 2.0, the results of the HRSC program confirmed the presence of a complex hydrogeological environment where the majority of the mass of the chlorinated volatile organic compounds (CVOCs) is contained within the low-permeability zones. The proposed remedies in the SFS are not technically capable of overcoming a slow diffusion rate-limited contaminant source such as the C1 clay zone and the INT within a reasonable length of time without inordinate cost. It was at this point that the phased approach to the design of the remedy changed from engineering feasibility and reliability to a TI evaluation for the site.

## 1.4 PRESENTATION STRUCTURE FOR TI COMPONENTS

The presentation of information in this report is consistent with the TI Guidance document as well as the type of information that has been proven to be most valuable in assessing the validity of a TI waiver.

This evaluation includes the following components, based on site-specific information and analyses:

1. Specific ARARs or media cleanup standards for which the TI determination are sought (Section 1.0);
2. The spatial area over which the TI decision will apply (Section 4.0);
3. A conceptual model that describes site geology, hydrology, ground water contamination sources, transport and fate (Section 2.0);
4. An evaluation of the restoration potential of the site, including data and analyses that support any assertion that attainment of ARARs or media cleanup standards is technically impracticable from an engineering perspective (Section 3.0). This includes:
    a. A demonstration that contamination sources have been identified and have been, or will be, removed and contained to the extent practicable (Section 3.1);
    b. An analysis of the performance of any ongoing or completed remedial actions (Sections 3.2 through 3.5);
    c. Predictive analyses of the timeframes to attain required cleanup levels using available technologies (Section 3.6); and
    d. A demonstration that no other remedial technologies (conventional or innovative) could reliably, logically, or feasibly attain the cleanup levels at the site within a reasonable timeframe (Section 4.0).
5. Estimates of the cost of the existing or proposed remedy options, including construction, operation, and maintenance costs (Section 5.0).

In 2012, the USEPA published OSWER Directive 9230.2-24, *Summary of Technical Impracticability Waivers at National Priorities List Sites*. This document summarizes the type of information that has been used by EPA to support a total of 91 TI waivers for federal Superfund Sites. Common factors that have been used in the past as justification for TI waivers include:

- *Geology and hydrogeology* – Complex geology was cited as a contributing factor in the rationale for 54 of the 85 ground water TI waivers and included fractured bedrock, karst terrain, and heterogeneous soils with low permeability.
- *Non-aqueous phase liquid (NAPL) and other contaminants* –DNAPL was included in 43 waivers in addition to relative immobility in the subsurface.

- *Timeframe* – With regard to considering the timeframe associated with achieving ARARs, of the 91 waivers, 56 had information about the timeframe. Most of those waivers (more than 90 percent) included timeframes of greater than 100 years.

This report describes how the TI waiver for the French Limited Site shares these same factors with other sites for which the EPA has approved TI waivers.

## 2.0 REFINED SITE CONCEPTUAL MODEL

As mentioned above, FLTG began the design study for the SFS-proposed remedy with a data gathering investigation. ERM conducted a high resolution source characterization (HRSC) program at the Central Plume Area, where concentrations of COCs have remained elevated since ground water remediation began. The HRSC program was performed in 2011, 2012 and 2013 and included data collection from cone penetrometer testing (CPT), a membrane interface probe (MIP) system and discrete-interval ground water sampling using the Waterloo Advanced Profiling System (Waterloo$^{APS}$).

The HRSC program focused on approximately 1.5 acres to the south of the SPW. The objective of the first part of the HRSC was to gather a large volume of high resolution geologic and semi-quantitative data on the distribution of COCs within the study area. This phase included the CPT/MIP program which investigated 26 boring locations in Central Plume Area. These data were interpreted to define the zones with elevated mass of COCs. Next, these zones were the target of a second phase of work where discrete-interval ground water sampling was conducted using the Waterloo$^{APS}$ to develop a vertical profile. The Waterloo$^{APS}$ program included collection of 44 discreet water samples at multiple depths from 12 boring locations. The high-resolution collaborative dataset generated during these two field programs was interpreted to develop a refined conceptual site model.

Appendix A includes a detailed report of the HRSC program. The CPT, MIP, and Waterloo$^{APS}$ individual logs and the combined CPT/MIT/ Waterloo$^{APS}$ logs are included in Appendices B through E, respectively. The remainder of this section presents the refined site conceptual model.

### 2.1 GEOLOGY

The site is underlain by a heterogeneous sequence of stratified alluvial deposits with grain sizes ranging from gravelly sand to clay. Historically, the upper 55 feet of the geologic sequence was referred to as the upper alluvial zone by O'Hayre et al (1993). The upper alluvial zone is underlain by the middle clayey zone (also referred to as the C2 clay and silt layer), which is considered to be an aquitard (O'Hayre et al, 1993). The upper alluvial zone contains the following units from top to bottom:

- UNC: relatively uniform silty clay layer present from about 13 ft. above mean sea level (MSL) to about 0 ft. MSL;
- S1: relatively uniform water-bearing sand unit containing sand over gravelly sand from about 0 ft. MSL to about -15 ft. MSL;
- C1: relatively uniform clay and silt layer present from about -15 ft. MSL to about -20 ft. MSL; and

- INT: heterogeneous water-bearing unit consisting of interbedded fine-grained sand and silt with clay zones present from approximately -20 ft. MSL to -40 ft. MSL.

New site-specific lithology models derived from the CPT and Waterloo$^{APS}$ data are presented in Figures 2-1 and 2-2. The original understanding of the near-surface stratigraphy of the area is shown in two geological cross-section maps obtained from Applied Hydrology International (AHA, dated February 2006), as shown in Figures 2-3 and 2-4.

## *2.2 EVALUATION OF PERMEABILITY*

The majority of the mass of the COCs at the site are contained within the low-permeability zones. The UNC cover is a thin layer of flood silt and clay that is too heterogeneous and thin to confine the S1. The S1 is relatively well-sorted, medium- to very-coarse-grained, unconsolidated sand with an average thickness of about 20 feet and a hydraulic conductivity approaching $10^{-3}$ centimeters per second (cm/sec; 30 feet per day (ft/day)). Well yields in the S1 unit in the Central Plume Area (CPA) ranged from 10 to 15 gallons per minute (gpm). The INT is an interbedded silt and fine-grained sand unit with thin clay zones.

Previous lithologic records suggested that the INT has an average thickness of about 20 feet. Early investigations of the hydraulic conductivity for the INT using both pump tests and slug tests reported an average value of approximately $10^{-4}$ cm/sec (3 ft/day; AHA, 1989) for wells completed in the West and Central Plume Areas. Well yields in the INT unit near the Central Plume Area were generally less than 0.5 gpm, except in areas where the C1 is absent and the S1 and INT are in direct contact. In areas near INT-166, INT-135 and INT-060-P3, the well yields for the INT were observed to be approximately two to three gpm. As part of the HRSC, Waterloo$^{APS}$ Index of Hydraulic Conductivity (Ik) data and discrete-interval ground water sampling equilibration times (Table 2-1) were used to evaluate the relative permeability of the geologic units discussed above. Based on interpretation of these relative permeability data, the S1 was determined to be the most permeable unit within the upper alluvial zone, which is consistent with historical data. The Ik values typically range from four to five, which is suggestive of hydraulic conductivity values on the order of $10^{-3}$ centimeters per second (cm/s) or greater, which is also consistent with historical data. In 19 of 20 discrete-interval ground water samples collected from this unit, sample flow rates greater than 30 milliliters per minute (mL/min) were achieved and geochemical equilibration occurred in less than 20 minutes, which is consistent with historical data indicating that this unit exhibits relatively high yields.

Collection of ground water samples from the C1 unit was not attempted due to the extremely low Waterloo$^{APS}$ Ik values (i.e., approaching zero), which are suggestive of hydraulic conductivity values on the order of $10^{-5}$ cm/s or lower, which is consistent with historical data.

The results of the HRSC demonstrated that the hydraulic conductivity of the INT unit is significantly lower than anticipated, based on review of the CPT and historical site data. The Ik values from this zone vary by up to five orders of magnitude, consistent with the lithology descriptions on the CPT logs and indicating significant heterogeneity. Based on review of ground water sample equilibration time data, only three discrete-interval ground water samples from the INT unit were collected at flow rates greater than 30 mL/min and in less than 20 minutes, which is indicative of moderate hydraulic conductivity (i.e., about $10^{-3}$ cm/s).

In contrast, 17 discrete-interval ground water samples from this unit required more than 30 minutes to equilibrate at rates between 2.2 mL/min and 19.4 mL/min, which is indicative of relatively low hydraulic conductivity (i.e., about $10^{-4}$ cm/s). In addition, ground water sample collection was attempted at over 10 different intervals, but was unsuccessful due to low hydraulic conductivity (i.e., less than $10^{-4}$ cm/s). Collectively, these data are consistent with the characterization of the INT unit as one with low hydraulic conductivity (i.e., on the order of $10^{-4}$ cm/s or lower) silts and clays with limited occurrences of discontinuous silts and fine-grained sand of moderate hydraulic conductivity.

A review of historical hydraulic conductivity (K) data collected from various locations across the site was completed to compare flow data for the Central Plume Area with the remainder of the site. As shown below in Table 2-2, the S1 K values and INT K values collected from wells across the site are consistent with the data collected from the Central Plume Area. Specifically, the S1 K values are all in the $10^{-3}$ cm/s order of magnitude; the INT K values are in the $10^{-4}$ to $10^{-5}$ cm/s magnitude.

***TABLE 2-2: Representative K-values Outside of the Central Plume Area***

| Well | Test Type | Method | K cm/s | Unit |
|---|---|---|---|---|
| REI-3-3 | Pump Test | Boulton Delayed Yield | 1.57E-03 | S1 |
| GW-3 | Slug Test | Bouwer & Rice | 3.80E-03 | S1 |
| GW-5 | Slug Test | Bouwer & Rice | 1.30E-03 | S1 |
| GW-7 | Slug Test | Bouwer & Rice | 2.30E-03 | S1 |
| REI-10-2 | Pump Test | Boulton Delayed Yield | 4.78E-04 | INT |
| REI-10-3 | Pump Test | Theis Recovery | 1.88E-05 | INT |

The IK values are generally consistent with the K values for the water-bearing units, indicating that the observed hydraulic conductivity values in the Central Plume Area are likely to be representative of the hydraulic conductivity for the West Plume and East Plume Areas. Based on the relative hydraulic conductivity results for each unit, the ground water flow rates are highest in the S1, slowest in C1 unit where vertical ground water flow is likely to be the dominant flow direction, and there is a slow ground water flow rate within the INT unit.

The implication of this part of the conceptual site model is that the low permeability of the INT unit reduces the potential to extract ground water or inject treatment amendments to restore ground water in within a reasonable length of time.

## *2.3 CONTAMINATION SOURCE AND RELEASE MECHANISM*

The source of the constituents of concern and the release mechanisms are well studied. The site accepted wastes from early 1966 to early 1971. Wastes were delivered to the site in barrels and tank trucks. The barrels were dumped and flattened, or they were buried in the lagoon. The liquid wastes were dumped into the lagoon or into separator tanks, where the saleable material was skimmed and sold. The bottoms were drained to the lagoon. A wide variety of wastes were placed in the lagoon: still bottoms, styrene tar residues, contaminated drilling muds, off-spec. petroleum products, waste oils, tank bottoms, and polychlorinated biphenyls (PCBs). The chemical contaminants are volatile organics, semi-volatile organics, base neutral organics, PCBs, and metals.

The lagoon was created by excavating the S1 sand for commercial purposes. The waste materials were placed in the lagoon where they were presumably in direct contact with the remaining portions of the S1 as well as the C1 clay zone. The benefit of the SPW is that it contains the residual source materials in the S1 and C1 clay zone in the Former Lagoon Area.

## *2.4 CONTAMINATION FATE AND TRANSPORT*

There are three areas of the site where COCs have consistently been identified in ground water (Figure 1-3):

- The East Plume Area;
- The Central Plume Area; and
- The West Plume Area.

Tertiary butyl alcohol (TBA) and benzene are present in ground water in both the S1 and INT in all three areas at concentrations above RAOs. Chlorinated hydrocarbons are present in site ground water in the S1 and INT at concentrations above RAOs. Vinyl chloride (VC) is present in ground water within the INT at concentrations above RAOs in an isolated area west of South Pond.

The fate and transport of COCs is limited by two factors:

- the complex geologic conditions and low-permeability zones constrain the diffusion of COCs from the C1 clay zone and INT, which reduces mass mobility; and
- the slow but steady natural attenuation of COCs degrades and retards the potential for migration of COCs within the S1 and INT.

A benefit of these factors is that they contribute to the long-term stability of the COCs at the site.

### 2.4.1 *Highly Variable Concentrations in the Central Plume Area*

The HRSC program was conducted in the Central Plume Area because it contains the most complex mixture of COCs and is in close proximity to the area where the SPW was expanded to address evidence of residual DNAPL. The distribution of COCs and the associated concentrations vary throughout the Central Plume Area. The majority of COC mass identified in this area is present within the low permeability C1 and along its interface with the overlying S1, and underlying INT. Figures 2-7 and 2-8, respectively, illustrate the distribution of COC mass, as well as the logs presented in Appendix E.

The relatively small portion of the total COC mass identified in the relatively high permeability S1 was attributed to back diffusion out of the underlying C1, as discussed in more detail below. Given that the vast majority of COC mass is present within the relatively low permeability C1 and INT, the potential for migration (i.e., mass flux or mass discharge) is limited by the low hydraulic conductivities and the partitioning of the COCs on the fine-grained sediments.

A variety of chemical signatures were identified in the Central Plume Area, some of which were enriched in disposed chemical products (e.g., tetrachloroethene (PCE) and possibly 1,2-dichloroethane (1,2-DCA), others were enriched in degradation constituents (e.g., cis-1,2-dichloroethene (cis-1,2-DCE), VC, and 1,1-dichloroethane (1,1-DCA), and yet other signatures were a mixture of both disposed chemicals and degradation products. Figure 2-9 illustrates 12 characteristic chemical signatures identified in the central Plume Area.

As shown on Figure 2-7, there is a mixture of primarily 12-DCA, chloroform, cis-12-DCE, and VC at the base of the S1 and diffused into the upper portion of the C1 at APS-07, APS-08, and APS-09, and is bounded to the east by MIP boring B-08. Of the HRSC study area, only one location was identified where a consistent chemical signature was detected at elevated concentrations (i.e., greater than 10,000 ug/L) in ground water.

Elsewhere, the distribution of chemical signatures is highly variable in both the vertical and horizontal dimensions over distances of only a few feet, indicating that intrinsic biodegradation of chemical products may be occurring in some areas, but not in other areas. Although the causes of the variability in concentrations over small scales is not known with certainty, these results are consistent with the findings of EPA (described below in Section 3.4) that intrinsic degradation processes are not capable of degrading the complex mixture of COCs within a reasonable time period.

TBA was detected at the highest concentrations and in more samples than other petroleum-related compounds reported in site ground water. TBA concentrations greater than 22,000 ug/L (i.e., 10 times the RAO) were detected in the following discrete-interval ground water samples:

- APS-01: 47.5 ft, 51.5 ft
- APS-04: 27 ft
- APS-09: 43.9 ft

Similar to the CVOC distribution, elevated TBA concentrations were observed over limited horizontal and vertical areas, suggesting a heterogeneous distribution of small pockets of elevated TBA mass. The implication of a complex COC mixture and its distribution in small isolated pockets is that it creates an impractical application of the remedies proposed in the SFS.

### 2.4.2 *Concentration Variability and Fate and Transport*

A review of the collaborative dataset indicates that the distribution of CVOCs and petroleum-related compounds is highly heterogeneous, and the lateral and vertical extent of zones containing elevated COC mass is limited, which is suggestive of localized pockets of elevated COC mass such as residual DNAPL. There is only one case where adjacent sampling locations exhibit elevated COC concentrations with similar chemical signatures, suggestive of a zone of elevated COC mass, as shown on Figure 2-9.

As discussed above, the interpretation of the high-resolution geologic and hydrogeologic dataset indicates that the S1 is the most likely ground water transport zone within the study area. Thus, COC mass present within the C1 and INT is considered to be generally immobile, except for limited back diffusion of COCs out of the C1 into the overlying S1. Two or more discrete-interval ground water samples were collected from the S1 layer in nine of 12 Waterloo$^{APS}$ borings (no discrete-interval ground water samples were collected from the S1 from APS-01, APS-02 or APS-05 as MIP data did not identify significant COC mass within the S1 or C1 at these locations). In eight of these nine borings, total CVOC and TBA concentrations decreased significantly with distance above the S1-C1 interface, as shown below in Table 2-3 and presented in Appendix E. This significant vertical concentration gradient is consistent with a COC concentration profile that originates in the C1 and diffuses upward into the S1. The result is a thin dissolved-phase plume at the interface between these two units.

***TABLE 2-3: Waterloo APS Concentration Data within S1 Unit***

| | Total CVOC Concentration (ug/L) | | TBA Concentration (ug/L) | | |
|---|---|---|---|---|---|
| **Waterloo$^{APS}$ Boring** | **Deepest Sample in S1 Layer** | **Shallowest Sample in S1 Layer** | **Deepest Sample in S1 Layer** | **Shallowest Sample in S1 Layer** | **Distance Between Samples (ft)** |
| APS-03 | 9,928 | 11.2 | 4,300 | ND | 8.7 |
| APS-04 | 58 | 0.78 | 39,000 | 3,600 | 4 |

| | Total CVOC Concentration (ug/L) | | TBA Concentration (ug/L) | | |
|---|---|---|---|---|---|
| Waterloo^APS Boring | Deepest Sample in S1 Layer | Shallowest Sample in S1 Layer | Deepest Sample in S1 Layer | Shallowest Sample in S1 Layer | Distance Between Samples (ft) |
| APS-06 | 122 | 63 | 6,400 | 660 | 3 |
| APS-07 | 54,176 | 6,878 | 6,200 | 1,200 | 3.6 |
| APS-08 | 87,277 | ND | 4,300 | ND | 4.5 |
| APS-09 | 8,320 | 25 | 7,100 | 1,300 | 9.34 |
| APS-10 | 37 | ND | 4,300 | ND | 4.2 |
| APS-11 | 5.18 | 43.1 | 980 | 1,200 | 5.2 |
| APS-12 | 58 | 17 | 1,700 | 1,000 | 4.9 |

Note: Back diffusion out of the C1 layer may not be solely responsible for the dissolved-phase concentrations reported in the S-1 at APS-11.

The West Plume Area is characterized by relatively small areas and low concentrations of TBA and benzene within the S1. The extent of TBA was first apparent after it became a COC for the site and part of the routine monitoring program in 2008. Benzene has been routinely monitored in the West Plume Area 1991. A review of the monitoring results indicated that concentrations are approaching the ROAs from natural attenuation processes.

### 2.4.3 *Biodegration Effects are Insufficient*

Evidence of intrinsic abiotic and anaerobic biological degradation of CVOCs exists within portions of the Central Plume Area, such as the presence of degradation products, such as cis-1,2-DCE, trans-1,2-dichloroethene (trans-1,2-DCE), VC, 1,1-DCA, 1,1-dichloroethene (1,1-DCE), and methylene chloride (MC). This evidence is especially shown within the deepest portion of the S1 layer where degradation products commonly represent the majority of CVOCs detected in ground water. A review of the MIP FID detector response data suggests that methane is present within the C1 layer (i.e., there are several areas exhibiting elevated FID responses with no corresponding ECD or PID responses, which is indicative of the presence of methane). These data suggest that the CVOCs mass within the C1 is biodegrading anaerobically as it diffuses into the overlying S1. Section 3.6 provides a discussion of the back diffusion mechanism and its implications for restoration.

This may be the same fate and transport mechanism responsible for the creation of a localized plume of VC in the West Plume Area. Decreasing benzene concentrations over time suggests significant biodegradation of this COC. However, there is no significant evidence for biodegradation of other COCs, such as TBA, 1,2-DCA and MC.

The Central Plume Area HRSC study was conducted over an approximately 1.5 acre area. For the remainder of the Central Plume Area, the extent of COC concentrations that exceed the RAOs in the S1 is related to TBA, VC and benzene that extend to S1-136 to the east and to S1-148 to the south. Other reported CVOCs (1,2-DCA and chloroform) are generally limited to the northern portion of the Central Plume Area, where concentrations exceeding 100 mg/L have been reported. In the INT, the same chemicals and concentration ranges are observed; however, the extent of affected ground water remains within the aerial extent of the S1 plume.

### 2.4.4 *Hydrological Features Affecting Fate and Transport*

As reported in the many investigations conducted since the 1980s, the S1 ground water (Figure 2-5) flow conditions are strongly influenced by interaction with surface water bodies and topographic features in the area. The potentiometric surface has very low relief in the central and eastern plume areas, where it tends to slope toward surface water bodies (including the East Slough, East Pond, and South Pond) during dry periods and away from these surface water bodies during wet periods. Greater topographic relief is evident in the southern portion of the area between U. S. Highway 90 and the closed Harris County Landfill southwest of the site. In those areas, ground water may mound under areas with higher ground elevation and slopes to low areas, particularly the South Pond (during dry seasons), where the former sand pit and an adjacent cypress swamp (South Pond Extension) comprise ground water discharge zones. Figure 2-5 presents an apparent wet season potentiometric surface where ground water is flowing away from the South Pond throughout much of the area of interest.

The INT potentiometric surface (Figure 2-6) also exhibits a shallow ground water gradient over the eastern and central portions of the site and is similarly affected by presence of surface water bodies. Ground water gradients are toward the water bodies, suggesting a pattern of ground water discharge in these areas upward into the overlying S1 which, in turn, discharges into the water bodies. The pond-affected pattern changes west of the South Pond and South Pond Extension, where the potentiometric surface increases in gradient to the West-Southwest and diverges from the S1 surface.

The surface water elevation of the South Pond impacts the S1 and INT of the Central and East Plume Areas and its elevation is the major controlling factor for plume movement in the Central and East Plume Areas. During times of higher water elevation in the Pond, because of increased precipitation or beaver damming, the ground water flow becomes radial from the pond, causing an easterly and northeasterly flow direction in the Central and East Plume Areas. Conversely, lower Pond elevations during the dry summer months tend to produce inward ground water flows from these areas toward the Pond. With these changing conditions, the overall extent of affected ground water has not significantly changed since the monitored natural attenuation remedy was implemented in 1995. Affected ground water in the Central Plume Area and the East Plume Area appear to be at equilibrium with the shifting role of the South Pond.

Although there are not surface water features in the West Plume Area, the elevated topographic surface of the Harris County Landfill does create a localized ground water mound in the S1 unit during wet periods. Overall, the Landfill does not appear to be having a significant effect on the fate and transport of COCs in the West Plume Area.

The East Plume Area is characterized by elevated TBA and benzene concentrations within the S1. The lateral distribution of TBA and benzene in the S1 is influence by surface water features including the East Slough and the East Pond. Depending on the season, these features are either recharging ground water in the S1 or capturing ground water from the S1. Both of these conditions help to attenuate concentrations of TBA and benzene in the S1 and help to limit the potential for migration.

## 3.0 RESTORATION POTENTIAL OF THE SITE

Ground water remedial activities have occurred for over 20 years at the site using many remedial technologies including containment, in-situ and ex-situ treatment, permeability enhancement, and natural attenuation processes. Table 3-1 provides a summary of the applied remedial technologies since the completion of the remedial investigations in 1986. Given the abundance of information on remedial technology application and performance, the purpose of this section is to evaluate the restoration potential for the site from a technical basis. In a simple view, this section will demonstrate the sustained changes in ground water concentrations that occurred throughout the plumes as a result of the various remedial technologies that have been designed and implemented. The data are presented and evaluated in an engineering perspective that focuses on the technical capacity to achieve the RAOs. The structure of this section is consistent with Section 4.3 of the EPA's TI Guidance Document.

***TABLE 3-1: Summary of Remedial Technologies and Significant Events***

| Date | Action |
|---|---|
| 1982-86 | Remedial investigations completed by FLTG. |
| 1987-88 | Pilot Studies for Biological Treatment of Lagoon Waste conducted by FLTG. |
| 1988 | The PRPs formed FLTG, Inc. to manage the response action. |
| March 1988 | Record of Decision signed. |
| July-December 1989 | Sheet pile wall constructed around lagoon. |
| 1992 | Biological treatment system operated on contents of lagoon. |
| 1992 | Ground water remediation system (pump & treat) operated on affected water-bearing S1 and INT sands outside the lagoon. |
| December 1993 | Biological treatment of lagoon contents completed. |
| June-July 1994 | INT-11 DNAPL area sheet pile wall installed. |
| January-March 1995 | Permeability enhancement program conducted at the west end of the Site (INT-20) increases pumping rates temporarily. |
| May 1995 | Remediation Summary Report, Part A, Lagoon Remediation Verification and Certificate of Completion. |
| December 1995 | Modeling shows residual COCs mass can attenuate within 10 years and achieve ROD RAOs. Active ground water remediation is completed. |
| January 1996 | Aggressive phosphate and oxygen injection program initiated prior to Site abandonment. |
| March 1996 | Remediation Summary Report: Part B, Active Aquifer Remediation Verification; Monitored Natural Attenuation (MNA) program begins. |
| July 1996 | Final Site Close Out Report. |

| Date | Action |
|---|---|
| March–June 1998 | Oxygen sparging and focused pumping of persistent affected ground water plumes outside of the sheet pile wall. |
| February 2002 | Second Five Year Review report prepared by EPA reports several areas of the Site remain above RAOs. |
| 2004 | NAPL Investigation near S1-123 and former Treatment Plant Areas. |
| February 2005 | EPA requests an assessment of the East Slough Area to define the location of a proposed containment wall. |
| June 2005 | Supplemental Ground Water Investigation Report submitted to EPA. |
| 2006 | Supplemental Feasibility Study (SFS) requested and submitted to EPA. |
| February 2007 | Third Five-Year Review Report prepared by EPA reported that MNA has not achieved RAOs within the ROD specified 10 year timeframe. |
| June 2007 | Letter from EPA providing list of additional COCs and RAOs. |
| 2007-2008 | Tier 1 and Tier 2 Treatability Studies Performed. |
| 2010 | Revised Supplemental Feasibility Study submitted to EPA. |
| August 2012 | Fourth Five-Year Review Report |
| 2013 | EPA requests FLTG to consider Technical Impracticability (TI) Waiver for the ground water within the SPW and the Site. |

## *3.1 SHEET PILE WALLS FOR SOURCE CONTROL*

The main source of COCs at the site was the Former Lagoon. The SPW was installed around the lagoon in between August 1989 and January 1990, as required by the Administrative Order for the site (CRCLA-VI-13-89). The purpose of the wall was to provide flood protection, because the lagoon had been flooded several times during the remedial investigations, and to contain the site for bio-treatment of affected sediments and surface water within the wall during 1992 to 1996. Today, the SPW provides a barrier isolating the residual COCs in the former lagoon area from the surrounding soil and ground water.

### *3.1.1 Overview of Sheet Pile Wall Construction*

The SPW was constructed of 0.375 in (9.525 mm) high-tensile carbon steel (ASTM A-572 Grade 60). During installation, the sheet pile was driven to a depth of approximately 50 to 60 feet below ground surface (ft bgs), leaving the top of the wall at an elevation of 28 feet Mean Sea Level (ft MSL) or one foot above the 100-year flood level of 27 ft MSL. The depth of the wall was designed to isolate the affected ground water associated with the Lagoon from the surrounding water-bearing zones as well as contain the residual source soil and DNAPL from migrating to the surrounding ground water.

The penetration depth of the sheet piles needed to control migration was determined to be -36 ft MSL. In a July 24, 1989 letter to FLTG's construction manager (ENSR), AHA identified three potential scour areas where the top of the C2 clay (the target depth of the SPW) occurred at a greater depth than was generally observed elsewhere at the site. The sheet piles in the identified areas were driven to a final penetration depth of -46 ft MSL (ENSR, 1989).

A review of the available boring logs compared the depth of the C2 clay aquitard and the depth at which the SPW was completed (approximately -36 ft MSL or -46 ft MSL). In some areas, the density of geological boring data are not sufficient for detailed analysis and the interpretations of geologic data can result in some difference in opinion on the location of the bottom of the INT unit. In general, most areas that were reviewed show the depth of the SPW to have been completed into the C2 clay. The distributions of COCs in the INT near the SPW are consistent with the finding that the SPW has been a long-term containment system for the Former Lagoon, reducing the potential for significant migration to the adjacent water-bearing units.

Other source control measures were implemented in July 1989 and January 1990. Remediation was conducted to address several areas to the north and west of the lagoon where waste materials were deposited in the sloughs from previous flood events. The affected media were pumped or excavated and placed in the lagoon for remediation.

The potential for residual DNAPL occurrence at INT-11 (a monitor well located outside of the original sheet pile wall) and concern about potential constituent migration were the reasons for the completion of an additional wall segment around the area, which is adjacent to the former Lagoon and north of Gulf Pump Road. The additional wall section, bordered by INT-120, INT-127 and INT-123 (Figure1-2), was installed in August 1995. Details about the wall construction and integrity testing are provided in the "*INT-11 DNAPL Area Cutoff Wall Installation and Permeability Certification Report*", (AHA, August 1995).

### *3.1.2 Historical Performance of Sheet Pile Wall*

The performance of the SPW as a barrier for the potential migration of residual DNAPL and dissolved-phase COCs from the former lagoon area has been monitored since the time of installation. A wall leakage test was conducted during August and September 1990 at P-5 and P-6, which are located on opposite sides of the SPW. A review of the results suggested some potential exists for fluid migration through wall joints or underneath the wall under a pumping condition (ENSR, 1991).

The need for integrity monitoring was mentioned in the USEPA's First Five-Year Review report (December 1994) and was addressed in the Site Closure Plan (SECI, 1996). The monitoring of the migration potential through the SPW is evaluated annually by measuring ground water elevations in nested monitor wells located on either side of the SPW. Three S1 well pairs span the wall to monitor the head differences and are generally located near the sections of the wall where the top of the C2 is deeper. These are, from East to West, S1-064/S1-126, S1-119/S1-121, and P-5/P-6.

The Site Closure Plan established the performance monitoring objectives for evaluating the integrity of the SPW as a barrier to migration. A higher ground water elevation on the outside of the SPW compared with the inside elevation was described as the desirable condition because it would reduce the potential for constituent migration through the SPW. The opposite was not desirable because of the potential for COC migration through the SPW. Table 3-2 presents the data from the March 8, 2013 measurements.

***TABLE 3-2: Potentiometric Surface Measurements along the SPW***

| Well Name | Location | Ground Water Elevation (ft MSL) March 8, 2013 | Gradient |
|---|---|---|---|
| S1-064 | Outside | 8.38 | 1.65 feet INWARD |
| S1-126 | Inside | 6.73 | |
| S1-121 | Outside | 9.54 | 2.83 feet INWARD |
| S1-119 | Inside | 6.71 | |
| P-5 | Outside | 10.22 | 3.05 feet INWARD |
| P-6 | Inside | 7.17 | |

These results are consistent with the desirable conditions expressed in the Site Closure Plan and approved by EPA.

### *3.1.3 Bioremediation of the Former Lagoon*

The bioremediation of the lagoon was the first application of bioremediation as an innovative technology at a Superfund Site (USEPA EPA520-F-93-004, Spring 1993). The remediation of an estimated 300,000 cubic yards of petrochemical waste and affected soil in the lagoon began in January 1992 and was completed in December 1993. The USEPA confirmed that FLTG had achieved RAOs for the lagoon wastes (Table 3-3) and FLTG initiated lagoon demobilization activities (equipment removal, dewatering, backfilling, grading and completing the final vegetated cover) in accordance with the "Lagoon Demobilization Plan," dated January, 1994.

***TABLE 3-3: 1988 ROD Specific Target Compounds and RAOs for Lagoon Remediation***

| Compound | Concentration Limit (mg/kg) |
|---|---|
| Vinyl chloride | 43 |
| Benzene | 14 |
| Benzo(a)pyrene | 9 |
| Total PCBs | 23 |
| Arsenic | 7 |

The USEPA issued the Certification of Completion and partial delisting of the Site following the lagoon remediation in May 1995.

## 3.2 SCOPE OF THE GROUND WATER REMEDY – 1996 TO 2013

Once the source area was contained and treated, the next phase of remediation addressed affected ground water. This section presents the decisions and technologies implemented for addressing affected ground water at the site since the cessation of the active remediation systems in 1995. The scope of the remedies and their respective performance gives insight into the complex chemical mixtures at the site and the complexity of the hydrogeology that inhibits remedial performance.

### 3.2.1 Ground Water Inside the Sheet Pile Wall

During discussions with the EPA in 2013 regarding the components of the Institutional Control Plan, the agency queried FLTG about the remedy for the INT ground water within the SPW. Since the completion of the Former Lagoon remedy in 1995, the EPA–approved ground water remedial efforts have applied to the area outside of the SPW. The working assumption since that time was that the SPW and cap were the final remedy for soil and ground water in the Former Lagoon Area.

Inside the SPW, the S1 was substantially removed during the historical sand and gravel operations that created the lagoon. Only the C1 clay zone and the underlying INT are believed to remain within the lagoon, and the residual S1 unit sands located between the margins of the Former Lagoon and the SPW.

Neither the Remediation Summary Report, Part A (soil) nor Part B (ground water) specifically addresses the closure of the ground water beneath the former lagoon and inside the SPW. The SPW is not mentioned in the 1988 ROD. A proposed ground-water remediation program for the area inside the SPW in the *Remedial Action Plan Volume I*, dated September 28, 1990 (by ENSR) in which Section 2.3.6.1 of this report, titled *Lagoon-Bottom Groundwater Remediation*, proposes a pump and treat program for the area referenced as "inside the migration reduction wall".

A subsequent remedial design report suggests that the installation of the ground water pump and treat wells inside the SPW was not practical during the implementation of the lagoon remediation. The *Site Remediation Summary Report, Part A Lagoon Remediation Verification (May 1995)* addresses closure of the lagoon sludges and soils and the *Remediation Summary Report: Part B, Active Aquifer Remediation Verification (March 1996)* addresses the closure of the ground water outside of the SPW. Of note, the EPA-approved *Site Closure Plan* (dated January 4, 1996), states the following:

Section 1.7.2. FLOODWALL DESIGN AND CONSTRUCTION (1.7.2.1. DESIGN):

*"The floodwall was designed and constructed to satisfy the requirements of Administrative Order Number CERCLA-VI-1389, established by the EPA and FLTG,*

*Inc…This was done to control chemical migration from the lagoon in the shallow alluvial zone aquifer during and after remediation activities."*

Section 2.2.2 INT ZONE REMEDIATION

*"Sampling INT wells outside the containment walls indicates that site criteria is achieved or will be achieved during the ten years of natural flushing."*

EPA concurrence on an approach for closure of ground water inside the SPW was developed in a project meeting held on November 21, 2013. Since 1995 when the soil closure was completed inside the SPW, ground water inside the SPW was not part of the ground water monitoring program or active remediation efforts. Refinement Notification RN-083 (dated March 10, 1995) described the affected ground water in the INT unit within the SPW as no longer included in the remedial efforts to reach RAOs. During the project meeting, the EPA Project Attorney proposed that a TI waiver of the RAOs be considered given the protectiveness of the existing SPW and soil cap remedy.

A waiver for the RAOs in the INT is consistent with the EPA-approved criteria for soil closure. The protection of ground water in the remaining S1 and the INT was not considered in the derivation of the ROD-listed RAOs for the soil and sludge. A comparison of the RAOs and the TCEQ ground water protection PCLs ($^{GW}Soil_{Ing}$) is presented below. The $^{GW}Soil_{Ing}$ are soil concentrations that are deemed acceptable for the protection of ground water.

***TABLE 3-4: RAOs for Lagoon Remediation and TRRP $^{GW}Soil_{Ing}$ PCLs***

| **Compound** | **RAO (mg/kg)** | ***$^{GW}Soil_{Ing}$ PCL*[1] (mg/kg)** |
|---|---|---|
| Vinyl chloride | 43 | 0.02 |
| Benzene | 14 | 0.026 |
| Benzo(a)pyrene | 9 | 7.64 |
| Total PCBs | 23 | 10.6 |
| Arsenic | 7 | 5.0 |

[1] – From TCEQ TRRP Tier 1 PCL Tables, June 2012

As shown in Table 3-4, the RAO concentrations are over 2,000 times greater than the TCEQ's ground water protection standards for VC. The listed COCs are only a few of the potential COCs contained in the still bottoms, styrene tar residues, contaminated drilling muds, off-spec. petroleum products, waste oils, tank bottoms, and PCBs solidified in the Former Lagoon. EPA approved attainment of the ROAs in the closure of the Former Lagoon and issued a Certificate of Completion in May 1995 (CH2M, 1995).

For these reasons, the restoration potential of the INT within the SPW was deemed to be insignificant and not appropriate for an engineering capability assessment.

### 3.2.2 *Ground Water Outside the Sheet Pile Wall*

Outside the SPW, the overall extent of affected ground water was greatly reduced and a significant amount of mass was removed as a result of the active remediation performed at the site. The investigation was performed in stages and the understanding of the extent of affected ground water and magnitude of concentrations changed with the expansion of the ground water monitoring network. In general, the historical maximum concentrations were reported pre-1992. Figures 3-1 through 3-12 show the comparison of historical plume extent to current plume extent. Two levels of contouring are presented: 1.) the COC RAO and 2.) 10 times the COC RAO. The figures show plume configurations based on the reported COC concentrations.

The comparisons show the S1 and INT plumes for benzene, 1,2-DCA, VC and TBA, which have been used since 2004 to represent the extents of affected ground water given their prevalence, mobility, and nature (i.e. aromatic hydrocarbons, chlorinated hydrocarbons and alcohols). Although the lateral extent and concentrations of COCs decreased in many areas over time, the plume areas continue to show that the ROD-approved remedy is not capable of achieving the RAOs within a reasonable timeframe.

The plumes are generally stationary and stable – with seasonal and temporal fluctuations around an average extent and concentration. As shown, the extent of affected ground water has decreased for 1,2-DCA, benzene, VC and TBA in the S1 and INT in the West Plume Area. The overall extent has decreased for 1,2-DCA, benzene, VC and TBA in the INT unit of the Central Plume. Natural attenuation from the low permeability of the C1 clay and the INT and degradation of certain COCs is are working to stabilize the plume.

The only areas where the extent has not shown a significant decrease is in the S1 unit of the East and Central Plume Areas. In these two areas, the extent continues to lie within the historical limits of the plumes. The plumes in these areas appear to be remnant plumes where the active remediation efforts of the 1990's were less effective in treating the affected subsoil and ground water. Recent upward trends within the plumes appear to be caused by the back diffusion of residual COC mass from the C1 as described in Section 2.2, Section 2.3 and Section 2.4. A review of Figure 3-1 through Figure 3-12 show that the location of the plumes have been sufficiently investigated and monitored to conclude that the mass of diffusing COCs is at equilibrium with the attenuation capacity of the S1 and INT units.

A series of concentration versus time plots for 1,2-DCA, benzene, VC and TBA are provided in Appendix G and show generally stable to decreasing trends near the perimeter of the East, Central and West Plume Areas in both S1 and INT units. Concentrations of TBA were reported above the RAO at S1-136, INT-169 in 2013 and at FLTG-014 in 2012 and 2013. Prior to this time, the reported concentrations were within the range of historical concentrations reported for these wells. The concentrations will be further evaluated with the results of the 2014 annual ground water monitoring event.

### *3.3 ACTIVE GROUND WATER REMEDIATION – 1992 TO 1995*

As reported in the Second Five-Year Review Report for the French Limited Superfund Site (EPA, 2002), the active ground water remediation phase took place between January 1992 and December 1995. Affected ground water from the Central Plume Area was recovered and treated in an above-ground biological treatment facility. Injection and recovery/treatment were initially conducted in a treatment area located between the SPW and approximately 200 feet south of Gulf Pump Road in early 1992. The treatment area was expanded westward, southward and eastward in remediation phases in both units between 1992 and 1995. As stated in the ROD,

> *The contaminated groundwater will be recovered and treated during implementation of the in situ biological treatment process. Groundwater recovery and treatment will continue until modeling shows that a reduction in the concentration of volatile organics to a level which attains the 10-6 Human Health Criteria can be achieved through natural attenuation in 10 years or less.*

The ground water and soils remediation system consisted of these elements:

1. Ground water migration was controlled by maintaining an overall inward horizontal hydraulic gradient toward the northern portion of the ground water plumes near the lagoon source area;
2. Extraction of impacted ground water with above-grade treatment using fixed-film bioreactors, an inclined plate separator, along with sand and carbon filters; and
3. Injection of clean water amended with nutrients, nitrate, and oxygen to enhance flushing of impacted ground water and to promote in-situ bio-remediation.

These components were reported to have removed and treated over 281,000,000 gallons of affected ground water and removed nearly 188 tons of mass, measured as Total Organic Carbon (FLTG Monthly Report, December 1995).

The active ground water remediation system at the site was comprised of two separate treatment systems; one for the S1 and one for the INT. The treatment of the ground water recovered from these two systems was managed at a single ground water treatment plant. Each system consisted of ground water extraction at recovery wells along with amended, clean water injection at the injection wells. Figure 3-13 and Figure 3-14 show the general layout of each system.

Under operating conditions, the ground water remediation systems promoted the northerly flow (toward the lagoon) through the injection of oxygen and nutrient-amended water along the southern periphery of each zone and recovery of affected ground water from the northern portion of each zone in the S1 and INT units. The affected ground water was captured and treated prior to discharge to the San Jacinto River.

The monthly project reports tabulated the injection and production volumes of the remediation system. The injection and production rates in the S1 generally exceeded the rates of the INT by nearly five-fold. A review of the rates and locations of several INT remediation wells throughout the site show that higher injection and production rates (> 1 gpm) in the INT unit are from remediation wells in or near an area where the C1 clay is absent as shown on Figure 1-3. A review of INT remediation system wells located where the C1 is present generally shows production rates less than 0.5 gpm with many less than 0.2 gpm. The larger saturated thickness and vertical flow from the S1 into the INT are believed to have supported the higher discharge rates.

In January 1995, a permeability enhancement program was conducted in an attempt to increase injection and production rates in the INT outside of the western end of the SPW. As reported, approximately 1,700 cubic feet of course sand amended with nutrients was pumped into more than a dozen locations in the INT. While the initial rate responses of injection and production wells in the area were favorable, rates soon dropped off to pre-enhancement levels and the program was terminated. This effort demonstrated that the low hydraulic conductivity nature of the INT could not be sustainably altered to improve the yield of affected ground water and expedite the remediation of the INT.

Ground water modeling was performed to evaluate the potential effect of natural attenuation processes on the residual concentrations of COCs present at the site. Using the ground water data from October 1995, the BIOTRANS program was used to model the concentrations of benzene, 1,2-DCA and VC during the 10 year period from 1995 to 2005. The results were presented to the EPA in the *Natural Attenuation Modeling Report*, AHA, December 1995 and indicated that the remediation had reduced the concentrations of COCs to levels that would attenuate within 10 years and be consistent with the requirements of the ROD. Soon afterward, the active remediation system was decommissioned. The Site Remediation Summary Report, Part B (March, 1996) provides a description of these events.

### *3.4 MONITORED NATURAL ATTENUATION GROUND WATER REMEDY - 1996 TO 2005*

The next phase of ground water remediation was accomplished using MNA, for which active monitoring and performance tracking began in 1996. The objective was to achieve the RAOs with in upper alluvial aquifer (S1 and INT units) within a 10-year period of time. The MNA remediation described in the ROD was implemented after a modeling study was submitted to EPA that demonstrated the RAOs for ground water could be attained within 10 years (by December 2005) via natural attenuation (AHA, 1995).

The natural attenuation modelling conducted by AHA in 1995 utilized Visual MODFLOW© to model ground water flow and BioTrans© to model the natural attenuation of the target compounds benzene, 1,2-DCA and VC. The results of the BioTrans© model predicted that enough DO and other electron acceptors were present to degrade the residual mass present in the ground water at the site. One of the key assumptions was that a balance in the attenuation stoichiometry was present that would supply electron acceptors. Over time, it appears as though an imbalance was present and caused a premature depletion of the available electron acceptors and reduced the amount of COC attenuation that occurred following active remediation.

Based on a current review of modeling results, the following limitations were present in the 1995 modeling effort:

- Chlorinated solvents naturally biodegrade or attenuate in a process called reductive dechlorination, where the chlorinated solvent serves as the electron acceptor. This modeling effort did not evaluate the disappearance of key COCs at the site.
- The assumption of a balance between COCs and electron acceptors was not representative of site conditions, and a premature depletion of the available electron acceptors was observed compared with the model predicted results; and
- The concept that the COC mass (benzene, 1,2-DCA and VC) could be accessed by electron acceptors was not valid. At the time of the modeling work, the knowledge of the back diffusion process of COC mass, and the significant mass trapped in low-permeable units, had not been developed.

The back-diffusion of residual COC mass from the C1 and INT units, a critical process at the site that was realized through the HRSC program, contributed to the premature depletion of available electron acceptors. As a result, the modelled electron acceptor demand was lower than expected - causing the model to over-estimate the amount of degradation that would take place over the 10 year period from 1995 to 2005.

During March through June 1998, oxygen injection was used to enhance biodegradation in selected areas where benzene and VC persisted in monitoring data. This activity was documented by an August 4, 1998 letter to EPA. Localized elevated dissolved oxygen concentrations were noted within a few days to a few weeks after oxygen addition at wells approximately 30 to 75 feet from the injection points. Since June 1998, non-augmented natural attenuation alone has been applied for the remediation of ground water.

The second five-year review (February 2002) reported some portions of the S1 and INT ground water units may not meet compliance criteria by the end of the MNA period in December 2005, and additional remedial actions may need to be evaluated. The third five-year review (March 2007) reported that there were several areas in both the S1 and INT units that were not achieving the remedial objectives. Several areas of the site continued to report elevated concentrations of COCs in ground water that seemed resistant to the MNA remedy, and the RAOs specified in the 1988 ROD were not achieved by December 2005. Bench scale testing of TBA and benzene biodegradation indicated terminal electron acceptors for MNA of TBA and benzene were not present; therefore, MNA alone is not an effective approach to the restoration of ground water for TBA and benzene.

The reported ground water concentrations remained above the RAOs, and the EPA declared that the MNA remedy had failed. In September 2006, a report authored by Dr. John Wilson of the EPA entitled *"Evaluation of the Contribution of Natural Biodegradation to Monitored Natural Attenuation of Tertiary Butyl Alcohol (TBA) and Benzene in Contaminated Ground Water at the French Limited NPL Site"*, (Wilson, 2006a) was released. The report on the biodegradation potential for some of the site's COCs stated:

> *"...there is no evidence of natural biological degradation of TBA or benzene in contaminated ground water at the site. Based on the lack of electron acceptors in the water, there is no assimilative capacity to support future biodegradation of TBA and benzene at the site. In the absence of natural biodegradation, natural attenuation cannot produce useful reductions in the concentrations of benzene and TBA in ground water at the French Limited NPL Site in the future. As a consequence, monitored natural attenuation as the sole remedy will not meet clean up goals at any foreseeable time in the future." "If a biological process is used to treat the TBA in contaminated ground water at the French Limited NPL Site, the contaminated ground water should be pumped to the surface, and treated with micro-organisms that use oxygen supplied from the atmosphere as the electron acceptor."*

In a companion study, Dr. Wilson studied the potential for aerobic biodegradation of benzene 1,2-DCA, TBA and VC in microorganisms constructed of ground water and soil from the INT (Wilson, 2006b) This study found evidence for aerobic biodegradation of benzene, 1,2-DCA, and vinyl chloride, but no aerobic biodegradation of TBA. The following is a direct quote from the study:

> *"If a biological process is used to treat the TBA in contaminated ground water at the French Limited NPL Site, the contaminated ground water should be pumped to the surface, and treated with micro-organisms that use oxygen supplied from the atmosphere as the electron acceptor."*

As described earlier in the results of the HRSC work in Section 2.2, the low permeability conditions in the INT are a constraint on ground water extraction rates and the timeframes for restoration are not reasonable.

Evidence of intrinsic abiotic and biological degradation of CVOCs exists within portions of the Central Plume Area, such as the presence of degradation products, c12DCE, t12DCE, VC, 11DCA, 11DCE, and MC. This is particularly true within the deepest portion of the S1 layer where degradation products are the majority of CVOCs detected in ground water.

### 3.5 EXPANDED LIST OF COCS AND NEW PLUME DELINEATION

In 2006, the EPA directed FLTG to develop RAOs for five additional COCs that were detected in ground water, but for which no ARARs were approved at the time of the ROD. The additional COCs were:

- 1,1-DCA
- Chloroform
- Naphthalene
- TBA
- Methyl Tertiary-Butyl Ether (MTBE)

Of the constituents monitored at the site, TBA has become the most prevalent constituent in frequency, concentration and extent because of its high solubility level and apparent lack of degradation. The addition of TBA to the list of COCs was a significant reason for the change in the ground water plume extent maps, which started showing a larger area of affected ground water in 2007 for the Central and East Plume Areas. Other COCs, such as benzene, 1,2-DCA and VC, were generally stable in concentration with no significant changes in extent since 1995.

### 3.6 RESTORATION TIMEFRAME ANALYSIS

Consistent with Section 4.3 of the TI Guidance, the timeframe needed to restore the ground water bearing zones to the RAOs is a factor for consideration in the engineering capability assessment of remedial alternatives and appropriateness of a TI waiver for ARARs in water-bearing zones. This subsection was prepared with the presumption that active remediation, consistent with the aggressive remedial techniques used in the 1992 to 1995 period, would be needed to restore ground water concentrations to the RAOs in a reasonable length of time.

The restoration period was estimated utilizing the Matrix Diffusion Toolkit, (Farhat, S.K., et.al, developed for the Environmental Security Technology Certification Program (ESTCP) by GSI Environmental Inc., Houston, Texas (http://www.cluin.org/download/contaminantfocus/dnapl/Detection_and_Site_Characterization/. The spreadsheet utility uses a square root model to calculate the diffusion rate from a low K zone (e.g. clay, silt) and then estimate the concentration of the COC in an adjacent ground water transmissive zone as a result of the diffusion. The input parameter to the model runs were site conditions (COC concentrations, matrix types, etc.) from the Central Plume in the INT unit for 1,2-DCA and Benzene in the S1 unit and TBA in the INT unit. The modeling data are provided in Appendix F.

The model runs provide estimates of the diffusion conditions of residual COC mass, as described in Section 2.4; the results are interpreted to show that the COC mass will continue to generate dissolved plumes at concentrations above the RAOs for decades to hundreds of years. For example, TBA in the West Plume was predicted to diffuse out of the C1 at concentrations above the RAO of 2.2 mg/L until 2139 (125 years). Table 3-5 presents a summary of the modelled results. The modeling data and a table of the input parameters are provided in Appendix F.

***TABLE 3-5: Summary of Modeled Mass Diffusion Timeframes***

| Constituent | Plume Area | Year(1) | Number of Years | Modeled/Predicted Concentration at Year (mg/L) |
|---|---|---|---|---|
| 1,2-DCA | Central INT | 2636 | 622 | 0.0049 |
| Benzene | Central S1 | 2155 | 141 | 0.0049 |
| TBA | West INT | 2139 | 125 | 2.19 |

(1) – The year when the modeled COC mass will back-diffuse concentrations less than the RAO.

Although these time periods may seem large, they are consistent with what have been modeled at other sites where matrix diffusion is occurring. As documented in Chapman and Parker (2005), at a site in Connecticut where a DNAPL source area was contained using a sheet-pile wall, it was estimated that "[a]fter 100 years of back diffusion, simulations indicate that only 42% of the aquitard mass present at the time of source isolation will have been removed [by back diffusion]." (p. 14) Geologic conditions at the Connecticut site are similar to those present at the FLTG site (i.e., high permeability sand layer over a low permeability silt layer). The authors also note that "back diffusion effects are not limited to chlorinated solvents or chemicals released as DNAPLs, because any high-concentration contaminant plume migrating past low-permeability layers within or at the bottom of the aquifer will result in back diffusion when plume concentrations decline." (p. 15)

This analysis shows the complexity and diversity of the challenges associated with restoration of ground water at the site within a reasonable period of time. Specifically, the modeled timeframes reflect the following constraints on remediation:

- Constituent sources in the C1 clay were identified during the HRSC assessment and cannot be removed from the fine-grained materials with reasonable and appropriate efforts;
- None of the remedial efforts to date have been successful in reducing the residual mass of COCs to the extent that ground water concentrations have attained the RAOs;
- The predictive analyses of the timeframes estimated greater than 100 years because remediation is a diffusion-limited process using available technologies; and
- As discussed throughout this document, none of the remedial technologies that were considered reliable, logical, and feasible (both conventional and innovative technologies) have attained the RAOs for the site within a reasonable timeframe.

## 4.0 *TECHNICAL CAPABILITIES OF OTHER REMEDIAL ALTERNATIVES TO RESTORE GROUND WATER*

Six remedial alternatives were considered for the area outside the SPW and presented in the Supplemental Feasibility Study (SFS) dated March 7, 2014. The nature of the COCs, the geology and hydrogeology of the site, and the treatment experience of the last 20 years of remediation were used to select these remedies. All of the remedial alternatives included, at a minimum, containment of the former lagoon area and INT-11 area as wells as some level of natural attenuation as part of the remedy to achieve the RAOs.

The remedial alternatives considered in the SFS were:

1. No Action;
2. Monitored Natural Attenuation;
3. In-Situ Chemical Oxidation with MNA;
4. Permeable Reactive Barriers with MNA;
5. Combined Ground Water Extraction, Constructed Wetland Treatment, ISCO, and MNA; and
6. Additional Containment Walls with MNA.

Based on individual and comparative analyses to identify the relative advantages and disadvantages of each alternative, Remedial Alternative 5 – Combined Ground Water Extraction, Constructed Wetland Treatment, ISCO, and MNA – was selected to target specific areas to achieve the remedial objectives within a reasonable length of time. The approach blended several different remedies applying them simultaneously across the site. This approach was deemed acceptable by TCEQ and EPA under the Letter of Approval of Supplemental Feasibility Study for French Limited Superfund Site dated June 27, 2012.

Since the SFS was developed, additional data have been collected through implementation of the HRSC program as the first phase in the remedial design process. As presented in Section 2 of this report, ground water extraction and in-situ chemical oxidation are no longer considered technically feasible for the site. The mass of the COCs in the Central Plume Area and elsewhere at the site is contained within the fine-grained sediments of the C1 clay zone and INT. The elevated concentrations in the uppermost water-bearing zone (S1 zone) appear to be the result of back diffusion from the underlying C1 zone.

The aggressive ground water remediation program implemented from 1992 to 1995 at the site attempted to remove sufficient mass of COCs from ground water bearing zones such that MNA would restore ground water over a 10 year period. The remedy failed to achieve the objective because the complex geology and nature of the COCs (including residual DNAPL) inhibit mass removal. If this aggressive approach, or something of similar scale and intensity were implemented today, the time frame estimated for restoration of ground water would be unreasonably long (more than 100 years).

## *5.0 REMEDIAL COST ESTIMATE*

Section 4.4.5 of the TI Guidance considers cost as a factor in the evaluation of TI waivers if the costs for a remedy alternative would be inordinately high. Cost is classified as subordinate to a remedy's protectiveness. For this site, there is a correlation between the estimated time frame needed to achieve the RAOs and the cost of achieving ARAR compliance.

This cost estimate is provided to show the potential cost difference that could be realized if the current remedial approach of Combined Ground Water Extraction, Constructed Wetland Treatment, ISCO, and MNA were converted to MNA with a TI waiver.

The estimated costs for the current remedial approach were developed as part of the SFS in 2006 and revised in 2010. These estimates were used as a basis for this cost estimate along with an update of unit prices, expanded implementation to reflect an effort consistent with the 1992 to 1995 remediation program, and the affected ground water presumed to occur in the INT beneath the former lagoon. Table 6-1 presents the estimated cost at approximately $22,000,000 for a 30-year operational period. The 30-year period was selected to represent an optimistic estimate of the duration of the ground water remedy. Assuming the diffusion-limited modeling results are representative of site conditions, this probability of success is likely to be very low and could result in a remedial cost estimate that could possibly exceed $100,000,000.

In contrast, the costs would be approximately $2,200,000 (10%) for a 30-year period if a TI waiver was implemented, resulting in an estimated cost reduction of $19,800,000 over an optimistic remedial performance scenario.

## 6.0 PROPOSED TI ZONES

In accordance with Section 4.3 of the TI Guidance document, the purpose of this section is to present the proposed TI Zone boundaries for the S1 and INT units. Within the TI Zone, FLTG is seeking a waiver on the application of RAOs for COCs in ground water. Outside of the TI Zone, the RAOs will apply. The lateral extent of the proposed TI Zone is shown on Figure 6-1. Vertically, the TI Zone will include the full saturated thickness of the INT, terminating at the top of the C2 clay.

USEPA, TCEQ, and FLTG have discussed the need to have a single, comprehensive TI Zone at the site based on the complexity of the site conditions. This approach is warranted because the source of the affected ground water is a single source; the former lagoon. Affected ground water extends away from the former lagoon area to form three areas that were defined during the phased investigation and remediation activities. Figure 6-1 illustrates the proposed TI Zone, which was based on and include the following areas:

- Former Lagoon Area – the area within the SPW that includes any remaining S1 unit and the underlying INT unit;
- Central Plume Area - encompassing the S1 and INT where benzene, VC, and TBA are the most distributed COCs for the S1 (Figures 3-1 through 3-4) and for the INT (Figures 3-9 through 3-12);
- East Plume Area – encompassing the S1 unit and following the extents of benzene and TBA (Figures 3-5 through 3-8); and
- West Plume Area – encompassing the S1 and INT units where the SI TI Zone is defined by benzene and TBA (Figures 3-1 through 3-4) and the INT TI Zone where benzene, VC, and TBA define the extent (Figures 3-9 through 3-12).

The extent of affected ground water outside the Former Lagoon Area was defined by the most-recent extent (March 2013) ground water monitoring results where concentrations exceeded the RAOs within the S1 and INT. To account for seasonal variations, the TI Zone boundary was extended approximately 140 feet (25% of the observed plume length) beyond the estimated extent of affected ground water at the site.

As described below in Section 7, an associated Compliance Zone boundary has been established approximately 250 feet outside of the TI Zone boundaries.

# 7.0 COMPLIANCE MONITORING

An associated Compliance Zone boundary has been established approximately 250 feet outside of the TI Zone boundaries, as shown on Figure 6-1. The Compliance Zone has been established to provide the following:

- Verification of compliance with ARARs within the proposed Compliance Zone;
- Verification that plume has not migrated to the monitor wells in the proposed Compliance Zone; and
- Time to take contingency measures as needed to address plume migration to the proposed Compliance Zone boundaries.

The proposed compliance monitoring was developed to provide attenuation monitoring points (AMPs) around the extent of affected ground water in the S1 and INT units to detect the potential for plume migration beyond its 2013 extent, but before the proposed TI boundary. In addition, the compliance monitor wells will be used to detect a breach of the proposed TI boundary should one occur, and to provide time to respond to a breach before it reaches a proposed Compliance Boundary.

The monitoring networks were located in areas where plume migration could reasonably occur so that it can be detected along with safety concerns in accessing certain area. The SPW is an effective barrier to the migration of affected ground water from the Former Lagoon Area. No monitoring networks are proposed for areas outside the SPW where no migration has occurred in past.

## 7.1 FORMER LAGOON AREA

As previously indicated, water level measurements inside and outside of the SPW will be used to monitor the effectiveness of the barrier to the migration of affected ground water utilizing the existing, approved monitoring network. No monitoring for COCs is proposed.

## 7.2 S1 UNIT ATTENTUATION MONITORING POINTS

These S1 plumes are generally located within the West, Central and East Areas of the site. As depicted in Figure 6-1, a subset of monitor wells were identified as AMPs to monitor the extent of the existing plumes and plume stability on an annual basis. The proposed AMPs include:

- West Plume Area AMPs within the S1: S1-033, S1-031, P-5, S1-051-P-3, S1-108A.
- Central & Eastern Plume area AMPs within the S1: S1-165, S1-161, S1-162, S1-139, ¸ S1-160, S1-136, S1-147, S1-169, S1-142, S1-106A, S1-151, and S1-121.

### 7.3 INT UNIT ATTENTUATION MONITORING POINTS

Two ground water plumes have been identified within the INT unit at the site. These INT plumes are generally located within the Central and East Areas of the site. As depicted in (Figure 6-1), the AMPs are:

- West Plume Area AMPs within the INT unit: INT-144, INT-148, INT-158, INT-160, INT-253, INT-162, INT-214, INT-150, INT-251, INT-060-P-3, and INT-108.
- Central Plume area AMPs within the S1 unit: INT-166, INT-167, INT-170, INT-154, INT-262, INT-259, INT-155, and FLTG-13

### 7.4 COMPLIANCE MONITORING NETWORK

#### 7.4.1 TI Zone Boundary Monitoring

A tiered network of monitor wells is proposed to monitor the perimeter of the proposed TI Zone for compliance purposes. This network of monitor wells uses pre-existing and proposed new monitor well locations. As shown on Figure 6-1, they are located outside the proposed TI Zone and inside a proposed Compliance Zone.

The TI boundary will be monitored on an annual basis for concentrations of site-specific COCs exceeding the RAOs utilizing the following network of S1 and INT monitor wells:

- Existing monitor well locations INT-149, INT-261, S1-140; and
- Proposed new monitor wells (to be installed) S1-401, INT-401; S1-402, INT-402; S1-403, INT-403; S1-404, INT-404; S1-408, SI-409.

#### 7.4.2 Compliance Boundary Monitoring

As a tiered approach and extra level of conservatism, a network of compliance monitor wells has been proposed as shown on Figure 6-1. The compliance zone monitor wells will be utilized to evaluate the extent of COC concentrations that may exceed the RAO at the TI boundary. If triggered, sampling will be completed semi-annually when the TI boundary wells are sampled. In this way, the compliance monitor wells will help evaluate the extent of the plume(s) and prepare mitigation steps to address a breach of the TI Zone.

The compliance zone monitoring will be completed utilizing the following network of S1 and INT monitor wells:

- Existing monitor well locations INT-152, INT-153, S1-141, S1-163; and
- Proposed new monitor wells (to be installed) S1-405, INT-405; S1-406, INT-406; and S1-407, INT-407.

# 8.0 *INSTITUTIONAL CONTROLS*

The FLTG Institutional Control Plan (ICP, ERM, 2013) has been reapproved by the USEPA sand TCEQ and will be implemented following the approval of the ROD amendment.  The institutional controls in the form of deed notices and/or restrictive covenants will be placed on the property owned by FLTG. FLTG will work with the remaining property owners to obtain concurrence for filing similar restrictions on the other affected properties.

The controls to be used will be informational in that they will provide details of the restrictions to the affected properties including location of the restriction, reason for the restriction and the contact information to obtain further information (e.g. FLTG, USEPA, and/or TCEQ).  For example, the installation of potable water wells that may contribute to plume migration or result in exposure without the approval and oversight of FLTG, USEPA or TCEQ will be prohibited. The controls will also prohibit any excavations without the approval and oversight of FLTG, USEPA or TCEQ.  These controls will be subject to periodic monitoring to insure that the mechanisms remain in place and to determine whether the controls are providing the protection required by the remedy. Advisories, in the form of signage, will also be placed in areas accessible to the public warning of the potential exposure should a trespass occur. Oversight of the implementation of the ICP will be provided as directed in the plan.

## 9.0 CONCLUSIONS

The FLTG has worked for over 30 years to find a reliable and feasible remedy for ground water at the site. Although the full-scale implementation of ground water remedies has removed an estimated 188 tons or more of constituent mass, the RAOs have not been achieved and are not likely to be achieved within a reasonable timeframe. This report provides an engineering evaluation of the specific circumstances of this site that make the ground water restoration potential technically impractical. The most reasonable and appropriate means of managing the affected ground water is a TI waiver of the RAOs for the COCs. The technical basis for this proposal is based on the following conclusions:

- A HRSC program used in-situ sampling and characterization techniques and demonstrated the presence of a complex, heterogeneous, geology where the majority of the mass of the COCs are trapped within low-permeability zones;
- The site geology requires that ground water remedies be specifically designed to address multiple small-scale areas with unique hydrogeological conditions;
- Removal of deep residual DNAPL trapped in fine-grained sediments is making it impractical for existing as well as innovative remedial technologies to restore ground water within a reasonable timeframe;
- EPA concluded that the decay potential of a prevalent and concentrated COC, TBA, was limited without ex-situ treatment;
- Modeling results estimated over 100 years or more of treatment to overcome the slow rate of diffusion of COCs from the fine-grained materials. The estimated costs for such duration of treatment ranges from $22,000,000 to possibly $100,000,000;
- A benefit of the complex geology is that much of the COC mass is contained within the low-permeability materials. The slow diffusion nature of the mass transfer stabilizes the plumes; and
- A single TI Zone is proposed with an associated compliance boundary to include the entire area of affected ground water.

The management of COCs in ground water will be protective of human health and the environmental because no significant migration of COCs has occurred since 1995. The SPW is an integral component of the TI Zone, containing affected ground water inside the former lagoon area. Outside the TI Zone, concentrations will be monitored and residual levels, below the RAOs, will continue to degrade.

With EPA concurrence, FLTG proposes to revise the Supplemental Feasibility Study to reflect the conclusions in this report and the proposal of a TI waiver for the COCs in the ground water plumes at the site.

# 10.0 ACRONYMS

| | |
|---|---|
| AMPs | Attenuation Monitoring Points |
| 1,1-DCA | 1,12-Dichloroethane |
| 1,2-DCA | 1, 2-Dichloroethane |
| 1,2-DCE | 1, 2-Dichloroethene |
| ARAR | Applicable or Relevant and Appropriate Requirement |
| C1 | Relatively uniform clay and silt layer present from about -15 ft. MSL to about -20 ft. MSL |
| C2 | The upper alluvial zone (UNC, S1, C1 and INT units) is underlain by the middle clayey zone (also referred to as the C2 clay and silt layer), which is considered to be an aquitard (O'Hayre et al, 1993). |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| cis-1,2-DCE | cis-1, 2-Dichloroethene |
| COCs | Constituents of Concern |
| CPT | Cone Penetrometer Testing |
| CVOCs | Chlorinated Volatile Organic Compounds |
| DNAPL | Dense Non-Aqueous Phase Liquid |
| EPA | U.S. Environmental Protection Agency |
| FLTG | French Limited Task Group |
| ft bgs | feet below ground surface |
| HRSC | High-Resolution Site Characterization |
| IK | Index of Hydraulic Conductivity |
| INT | Intermediate water-bearing unit under the site, consisting of interbedded fine sand and silt from approximately -20 ft. MSL to -40 ft. MSL |
| K | Hydraulic Conductivity |
| ISCO | In Situ Chemical Oxidation |
| MCLs | Maximum Contaminant Levels |
| MIP | Membrane Interface Probe |
| MNA | Monitored Natural Attenuation |
| MSL | Mean Sea Level |
| MTBE | Methyl Tertiary-Butyl Ether |
| NCP | National Contingency Plan |

| | |
|---|---|
| NPL | National Priorities List |
| PCLs | Protective Concentration Levels |
| PCBs | Polychlorinated Biphenyls |
| PRPs | Potentially Responsible Parties |
| RAOs | Remedial Action Objectives |
| ROD | Record of Decision |
| S1 | Uppermost (shallow) relatively uniform water-bearing sand unit containing sand over gravelly sand from about 0 ft. MSL to about -15 ft. MSL |
| S2 | Deep water-bearing unit under the site, consisting of silty fine sand, occurring at the approximate depth interval of 120-145 ft bgs |
| SFS | Supplemental Feasibility Study |
| SPW | Sheet Pile Wall |
| TBA | Tertiary Butyl Alcohol |
| TCEQ | Texas Commission on Environmental Quality |
| TI | Technical Impracticability |
| trans-12-DCE | trans-1,2-dichloroethene |
| TRRP | Texas Risk Reduction Program |
| UNC | Relatively uniform silty clay layer present from about 13 ft. above mean sea level (MSL) to about 0 ft. MSL |
| Waterloo$^{APS}$ | Waterloo Advanced Profiling System |
| VC | Vinyl Chloride |
| VOCs | Volatile Organic Constituents |

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# Tables

*April 2, 2014*
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000

TABLE 1-1

Constituents of Concern and Remedial Action Objectives for Ground Water

Technical Impracticability Evaluation for Ground Water Restoration
French Limited Superfund Site
Crosby, Texas

| Constituents of Concern | CAS No. | Ground Water Concentration (mg/L) | | | |
|---|---|---|---|---|---|
| | | | TCEQ PCL | | |
| | | MCL | Residential | Commercial/ Industrial | RAO |
| | | | ${}^{GW}GW_{Ing}$ | ${}^{GW}GW_{Ing}$ | |
| 1,1-Dichloroethane | 107-06-2 | NA | 2.4 | 7.3 | 7.3 (a) |
| 1,1-Dichloroethene | 75-34-3 | 0.007 | 0.007 | 0.007 | 0.007 |
| 1,2-Dichloroethane | 107-06-2 | 0.005 | 0.005 | 0.005 | 0.005 (b) |
| Benzene | 71-43-2 | 0.005 | 0.005 | 0.005 | 0.005 (b) |
| Carbon Tetrachloride | 56-23-5 | 0.005 | 0.005 | 0.005 | 0.005 |
| Chloroform | 67-66-3 | NA | 0.24 | 0.73 | 0.08 (b) |
| Cis-1,2-Dichloroethene | 156-59-2 | 0.07 | 0.07 | 0.07 | 0.07 (b) |
| Methylene Chloride | 75-09-2 | 0.005 | 0.005 | 0.005 | 0.005 |
| Tert-Butyl Alcohol (TBA) | 75-65-0 | NA | 2.2 | 6.6 | 2.2 (0.26) (b) |
| Tetrachloroethene | 127-18-4 | 0.005 | 0.005 | 0.005 | 0.005 (b) |
| Trans-1,2-Dichloroethene | 156-60-5 | 0.1 | 0.1 | 0.1 | 0.1 |
| Trichloroethene | 79-01-6 | 0.005 | 0.005 | 0.005 | 0.005 (b) |
| Vinyl Chloride | 75-01-4 | 0.002 | 0.002 | 0.002 | 0.002 (b) |

NOTES:

(a) Tier 1 Industrial/Commercial PCLs are listed as placeholders for those constituents without MCLs or specified RAOs.

(b) RAOs were provided to FLTG, Inc. in a letter from USEPA dated June 15, 2007. TBA RAOs were listed for both non-carcinogenic (2.2 mg/L) and carcinogenic (0.26 mg/L) toxicity criteria. The non-carcinogenic RAO is applied at the site.

Abbreviations:
${}^{GW}GW_{Ing}$ = Ground Water Ingestion
MCL = EPA's Maximum Contaminant Level
NA = Not Available
PCL = Protective Concentration Level
RAO = Remedial Action Objective
TCEQ = Texas Commission on Environmental Quality

TABLE 2-1

Waterloo$^{APS}$ Purge Rates

Technical Impracticability Evaluation for Ground Water Restoration
French Limited Superfund Site
Crosby, Texas

| Sample Name/Location | Depth (ft bgs) | Equilibration Time (mins) | Volume Purged (mLs) | Rate |
|---|---|---|---|---|
| APS-01 | 47.5 | 46 | 700 | 15.2 |
| APS-01 | 51.5 | 43 | 450 | 10.5 |
| APS-02 | 39.1 | 22 | 600 | 27.3 |
| APS-02 | 43 | 51 | 400 | 7.8 |
| APS-02 | 48.7 | 20 | 650 | 32.5 |
| APS-03 | 24 | 10 | 600 | 60.0 |
| APS-03 | 27.7 | 8 | 400 | 50.0 |
| APS-03 | 44 | 20 | 400 | 20.0 |
| APS-03 | 40 | 72 | 400 | 5.6 |
| APS-03 | 19 | 13 | 900 | 69.2 |
| APS-04 | 23 | 8 | 500 | 62.5 |
| APS-04 | 27 | 15 | 700 | 46.7 |
| APS-04 | 36.2 | 36 | 700 | 19.4 |
| APS-04 | 45.5 | 36 | 80 | 2.2 |
| APS-05 | 37 | 86 | 500 | 5.8 |
| APS-05 | 48.7 | NC | NC | ND |
| APS-05 | 49.2 | NC | NC | ND |
| APS-05 | 51.9 | 71 | 300 | 4.2 |
| APS-06 | 23 | 8 | 600 | 75.0 |
| APS-06 | 28 | 10 | 600 | 60.0 |
| APS-06 | 38.8 | 58 | 600 | 10.3 |
| APS-06 | 41.76 | 46 | 500 | 10.9 |
| APS-07 | 23.4 | 5 | 350 | 70.0 |
| APS-07 | 27 | 16 | 1000 | 62.5 |
| APS-07 | 32.2 | 48 | 450 | 9.4 |
| APS-07 | 40.8 | 67 | 450 | 6.7 |
| APS-07 | 45.5 | 66 | 400 | 6.1 |
| APS-07 | 52.7 | 91 | 450 | 4.9 |
| APS-08 | 20.1 | 42 | 600 | 14.3 |
| APS-08 | 24.6 | 18 | 700 | 38.9 |
| APS-08 | 42 | NC | NC | ND |
| APS-09 | 17 | 7 | 600 | 85.7 |
| APS-09 | 22 | 10 | 700 | 70.0 |
| APS-09 | 26.34 | 12 | 500 | 41.7 |
| APS-09 | 43.88 | 17 | 750 | 44.1 |
| APS-10 | 21 | 10 | 600 | 60.0 |
| APS-10 | 25.2 | 9 | 650 | 72.2 |
| APS-10 | 45.2 | 53 | 300 | 5.7 |
| APS-11 | 21 | 11 | 900 | 81.8 |
| APS-11 | 26.2 | 11 | 900 | 81.8 |
| APS-11 | 36.6 | 27 | 400 | 14.8 |
| APS-11 | 50.6 | 24 | 400 | 16.7 |
| APS-12 | 22 | 14 | 1100 | 78.6 |
| APS-12 | 26.9 | 11 | 900 | 81.8 |
| APS-12 | 34.3 | 62 | 400 | 6.5 |
| APS-12 | 39.1 | 43 | 400 | 9.3 |
| APS-12 | 44.5 | 14 | 800 | 57.1 |

NOTES:
NC = Not collected
ND = Not Determined

TABLE 6-1

Remedial Cost Estimates

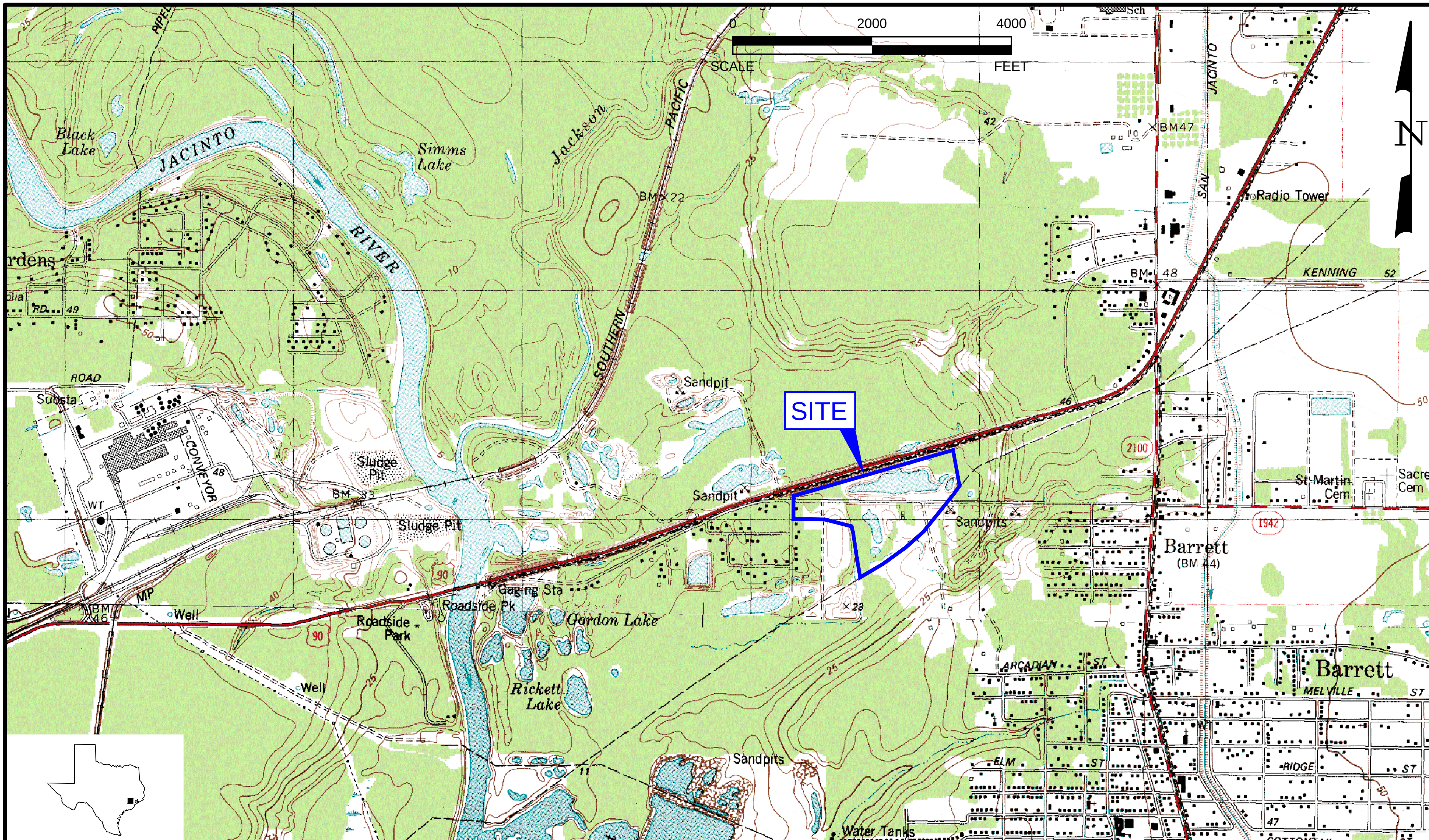
Technical Impracticability Waiver Evaluation for Ground Water Restoration
French Limited Superfund Site
Crosby, Texas

| Alternative | | Remedy Components | Estimated Costs |
|---|---|---|---|
| Alternative 1<br>No Action | 1 | Engineering | $ - |
| | 2 | Construction | $ - |
| | 3 | Monitoring | $ 480,000 |
| | | Subtotal | $ 480,000 |
| | | Contingency (40%) | $ 192,000 |
| | | Estimated Total Cost | $ 672,000 |
| Alternative 2<br>Monitored Natural Attenuation | 1 | Engineering | $ - |
| | 2 | Construction | $ - |
| | 3 | Monitoring | $ 1,566,000 |
| | | Subtotal | $ 1,566,000 |
| | | Contingency (40%) | $ 626,400 |
| | | Estimated Total Cost | $ 2,200,000 |
| Alternative 5 (as submitted)<br>Combined Ground Water Extraction, Constructed Wetland Treatment, ISCO, and MNA | 1 | Engineering | $ 365,000 |
| | 2 | Construction | $ 1,458,000 |
| | 3 | Monitoring & O&M | $ 1,050,000 |
| | | Subtotal | $ 2,873,000 |
| | | Contingency (40%) | $ 1,149,200 |
| | | Estimated Total Cost | $ 4,030,000 |
| Alternative 5 (Revised)<br>Combined Ground Water Extraction, Constructed Wetland Treatment, ISCO, and MNA | 1 | Engineering | $ 2,392,000 |
| | 2 | Construction | $ 7,972,000 |
| | 3 | Monitoring & O&M | $ 5,195,504 |
| | | Subtotal | $ 15,559,504 |
| | | Contingency (40%) | $ 6,223,802 |
| | | Estimated Total Cost | $ 22,000,000 |

# Figures

*April 2, 2014*
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000




SOURCE: U.S.G.S. 7.5' QUADRANGLES, CROSBY, TX (o29095H1) 1982 AND HIGHLANDS, TX (o29095G1) 1982.

**Environmental Resources Management**

| | | |
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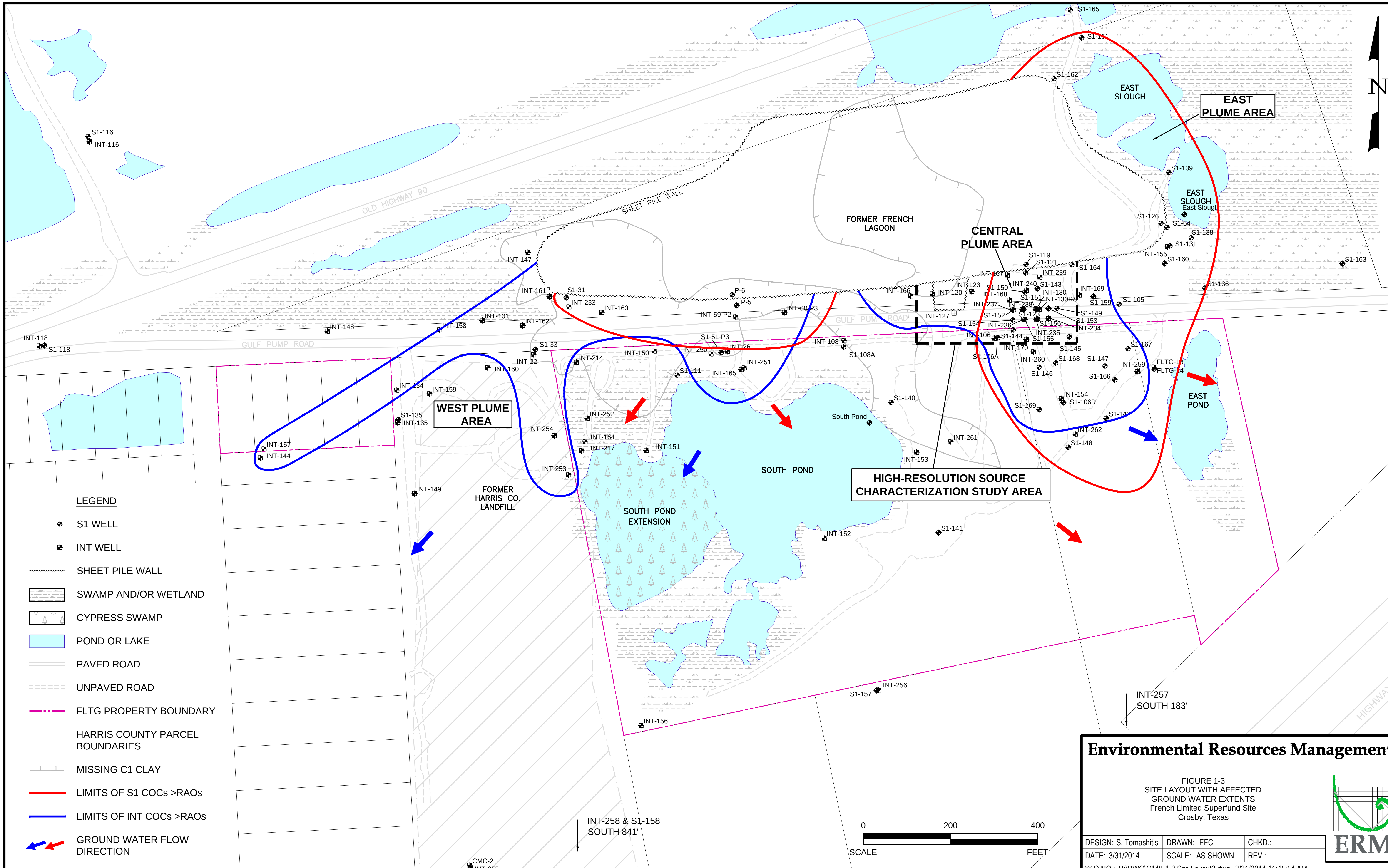
| PROJ. NO.: H:\DWG\C14\FrenchLtd\0234672 FIG1-2.dwg , 3/31/2014 11:44:41 AM | | |

FIGURE 1-2
SITE LOCATION MAP
French Limited Superfund Site
Crosby, Texas

ERM




**Environmental Resources Management**

FIGURE 1-3
SITE LAYOUT WITH AFFECTED GROUND WATER EXTENTS
French Limited Superfund Site
Crosby, Texas

ERM

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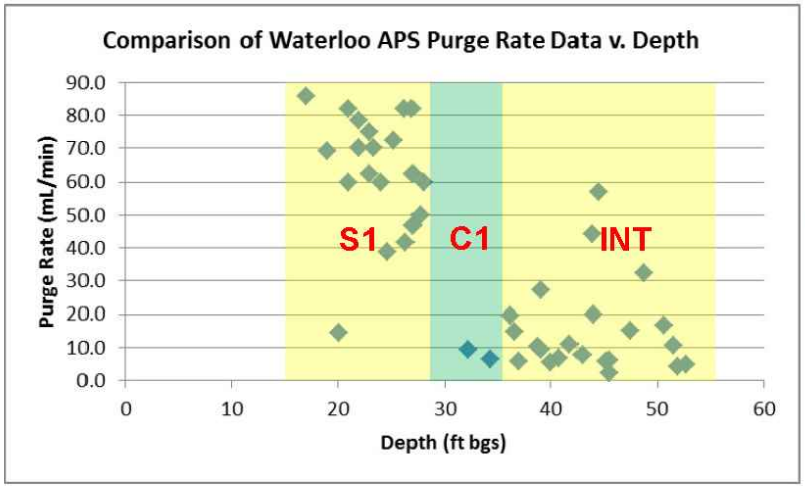


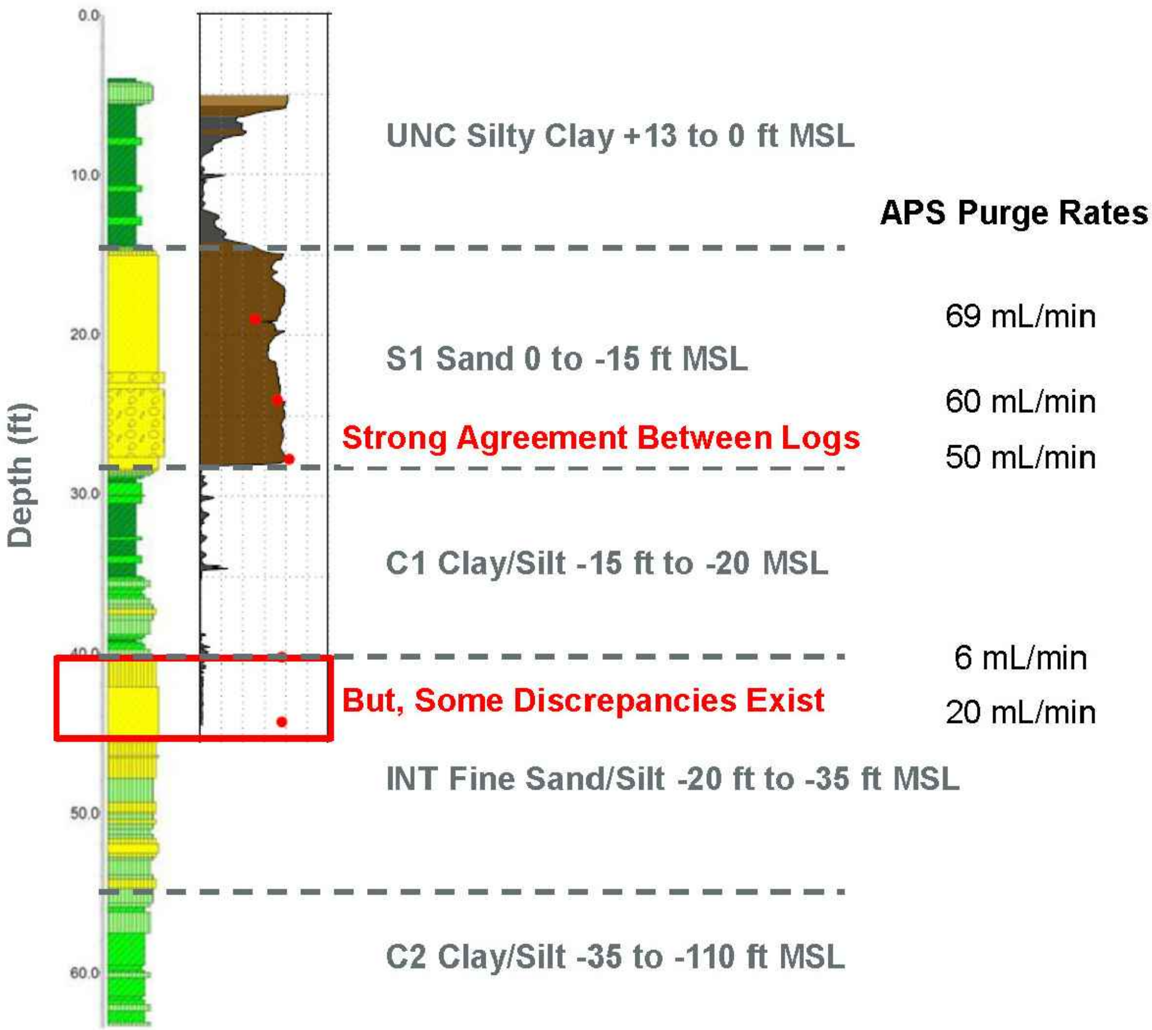


**Environmental Resources Management**

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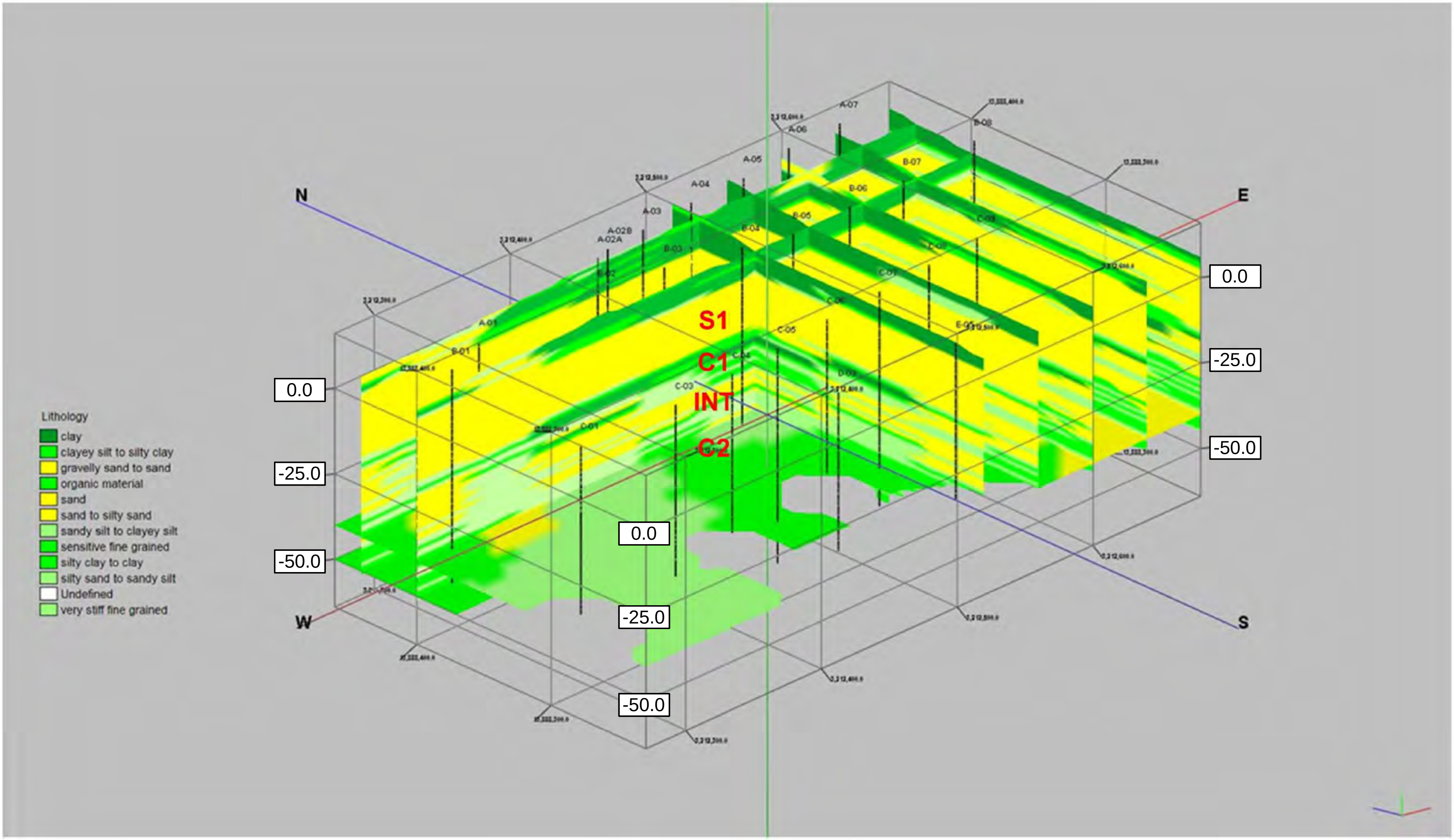
Figure 2-1
A-03 CPT Lithology & APS-03 Waterloo APS Hydrostratigraphy Data
French Limited Superfund Site
Crosby, Texas

ERM

ERM-Southwest, Inc. TX PE Firm No. 2393




ERM-Southwest, Inc. TX PE Firm No. 2393

**Environmental Resources Management**

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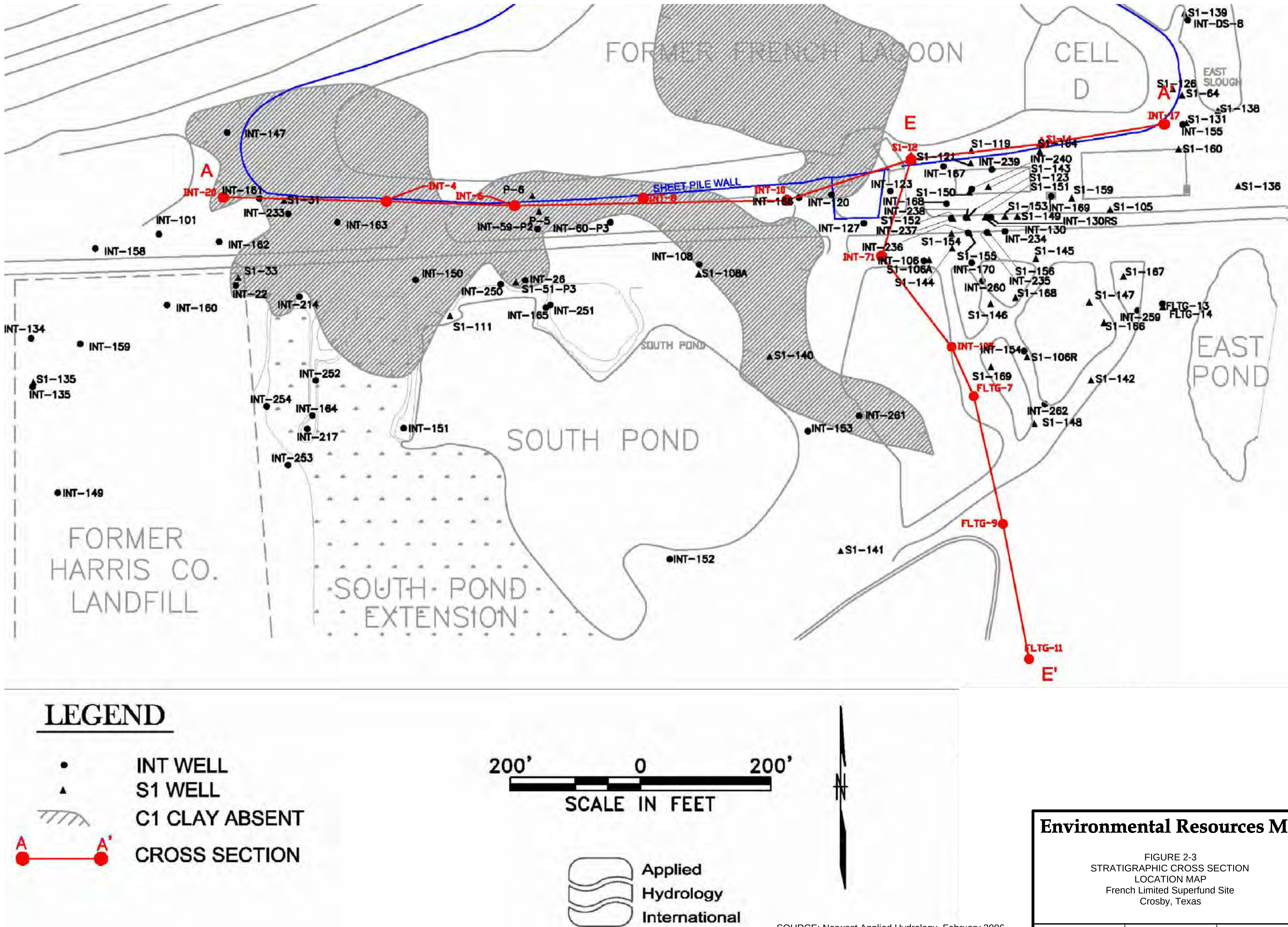
Figure 2-2
3D Lithology Model Developed Using CPT Data
French Limited Superfund Site
Crosby, Texas

ERM




Applied Hydrology International

SOURCE: Norwest Applied Hydrology, February 2006, *Supplemental Ground Water Investigation Report, FLTG, Inc. French Limited Superfund Site, Crosby, Texas*

**Environmental Resources Management**

FIGURE 2-3
STRATIGRAPHIC CROSS SECTION
LOCATION MAP
French Limited Superfund Site
Crosby, Texas

ERM

| DESIGN: CY | DRAWN: RLM | CHKD.: CY |
|---|---|---|
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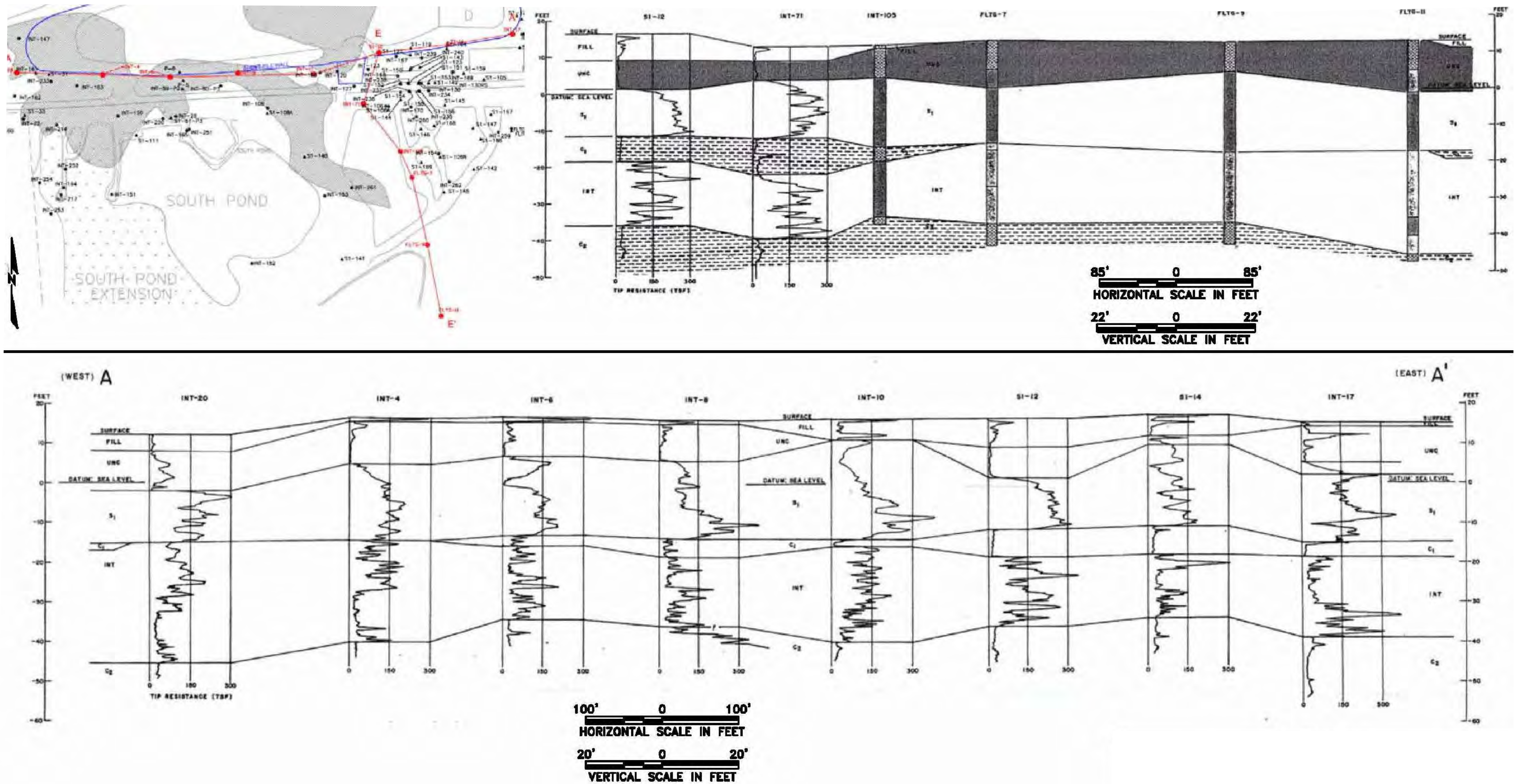


SOURCE: Norwest Applied Hydrology, February 2006, *Supplemental Ground Water Investigation Report, FLTG, Inc. French Limited Superfund Site, Crosby, Texas*

**Environmental Resources Management**

FIGURE 2-4
STRATIGRAPHIC CROSS SECTION
French Limited Superfund Site
Crosby, Texas

| | | |
|---|---|---|
| DESIGN: CY | DRAWN: RLM | CHKD.: CY |
| DATE: 3/27/2014 | SCALE: AS SHOWN | REV.: |

W.O.NO.: H:\DWG\C14\FrenchLtd\0234672 FIG 2-3-4.dwg , 3/27/2014 3:53:04 PM

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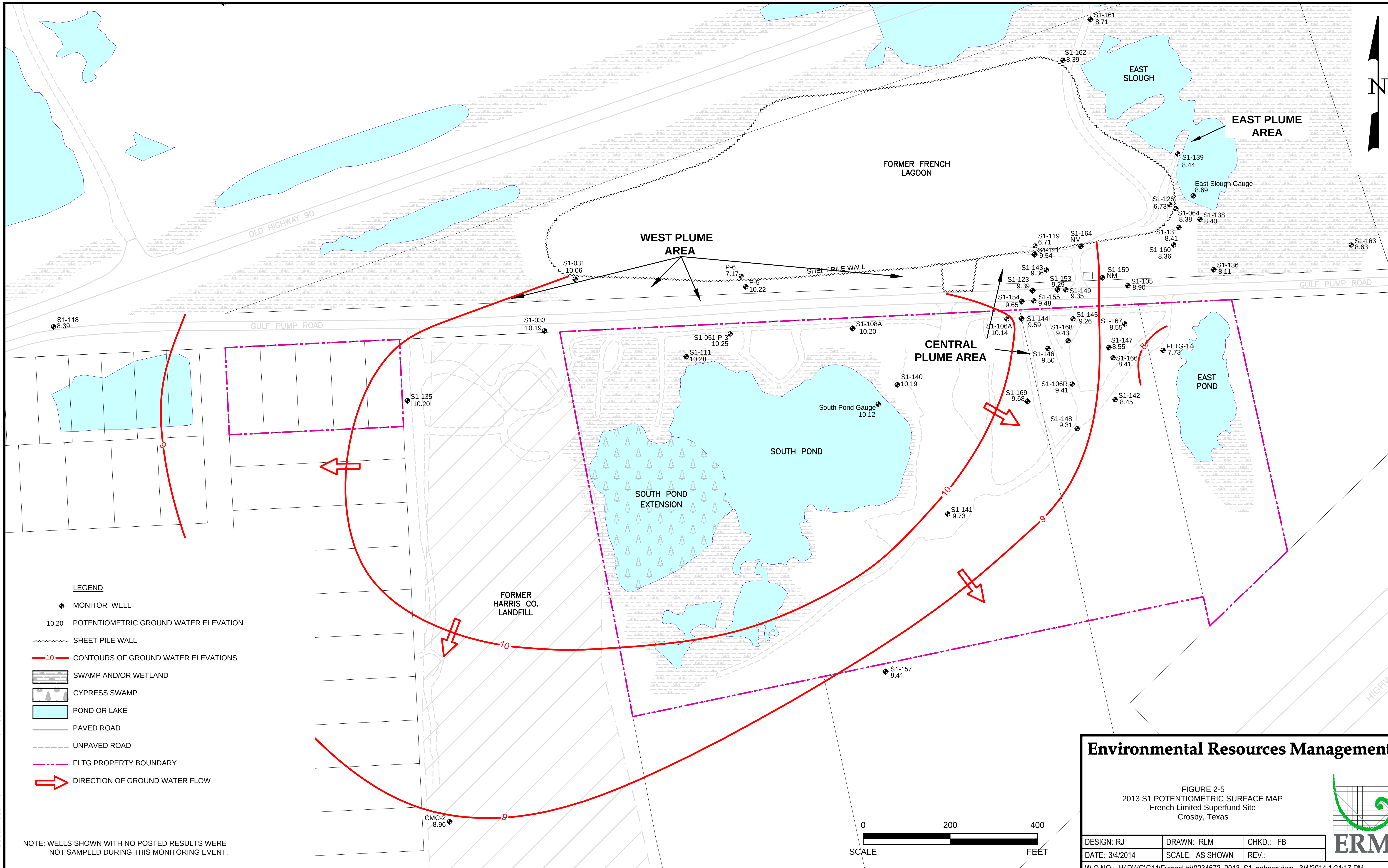
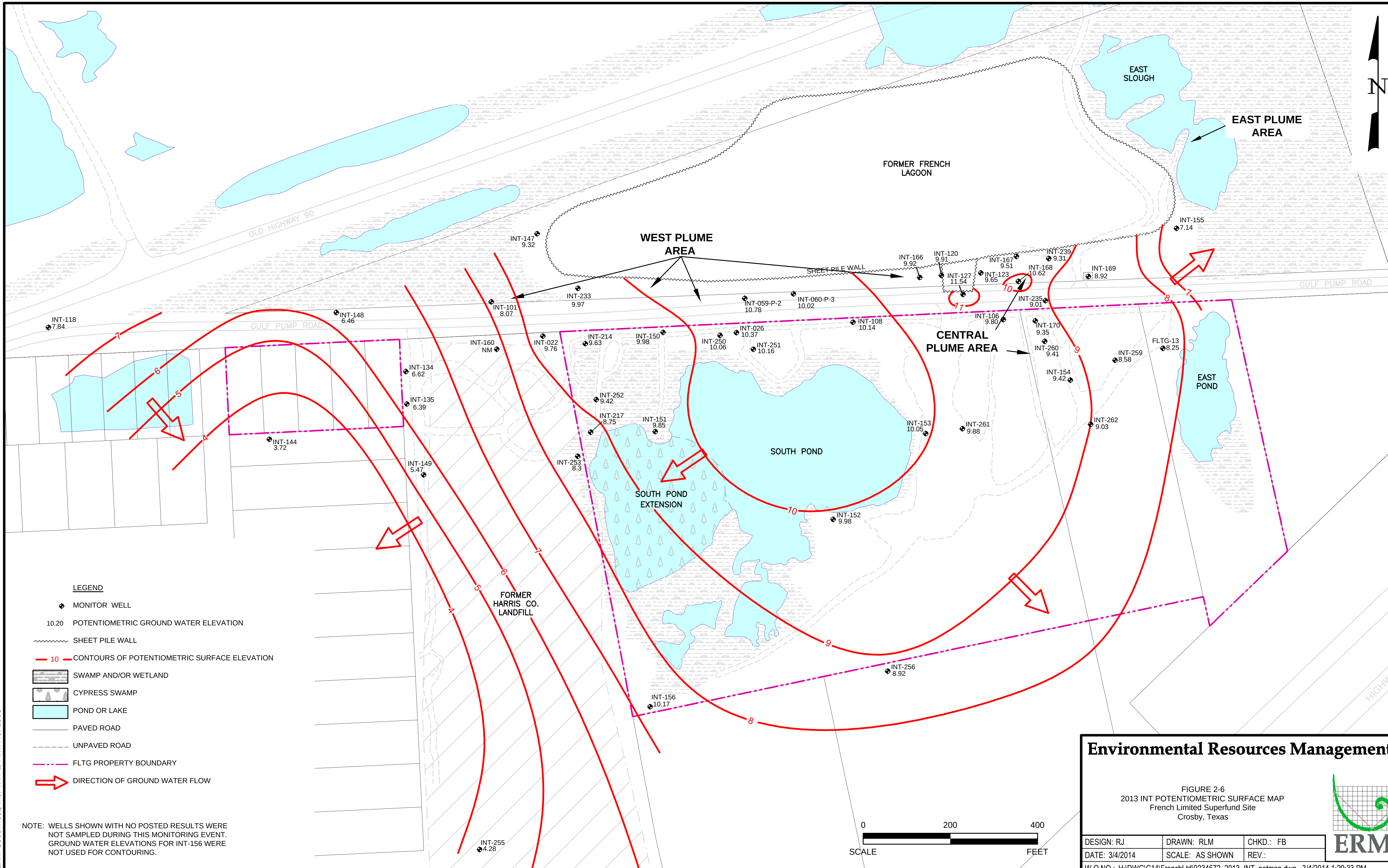



ERM-Southwest, Inc. TX PE Firm No. 2393

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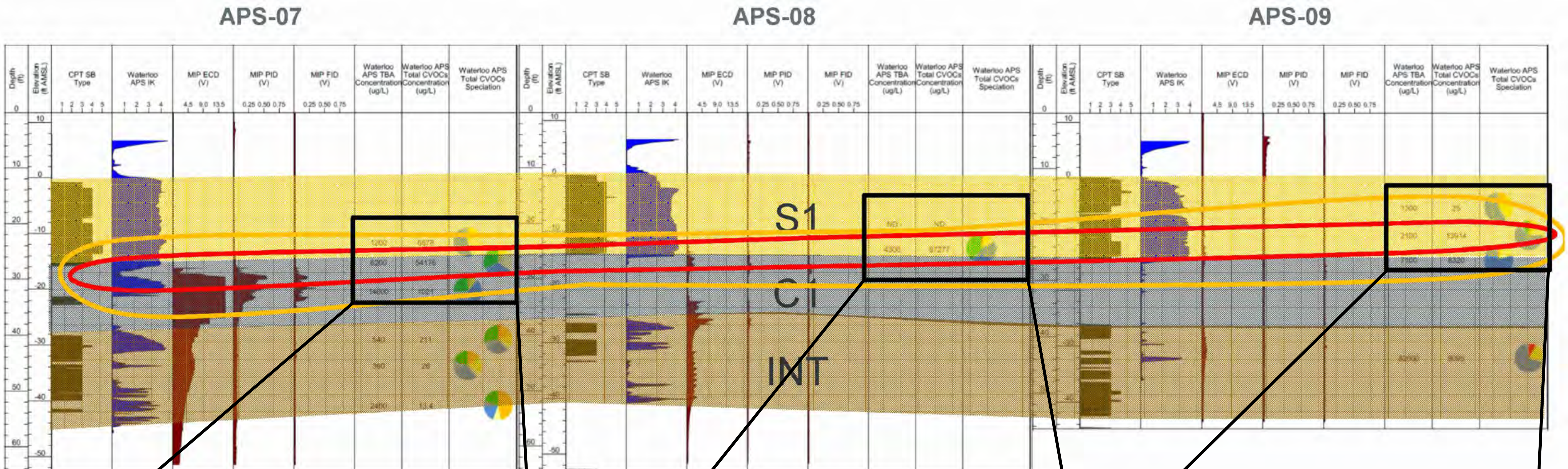
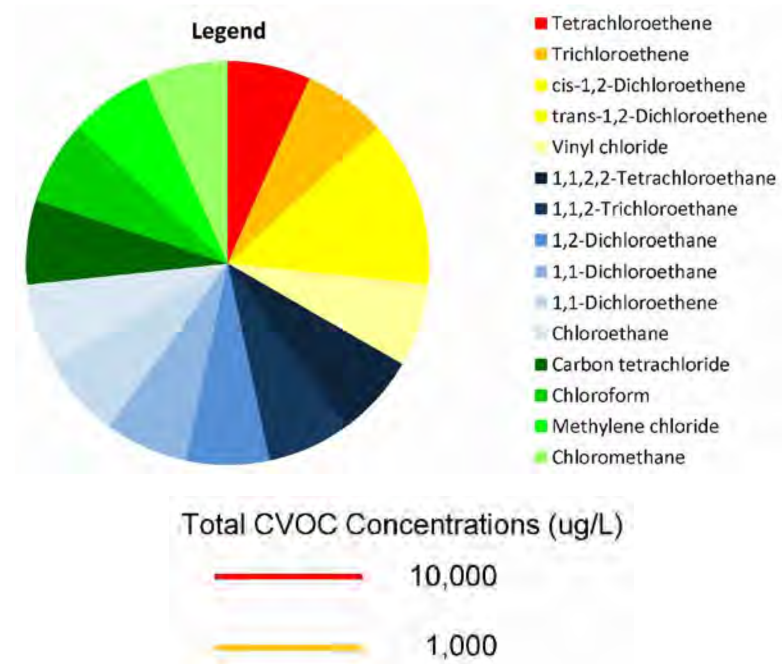



| TBA | Total CVOCs | |
|---|---|---|
| 1,200 | 6,878 | APS-07-23.4 |
| 6,200 | 54,176 | APS-07-27 |
| 14,000 | 1,021 | APS-07-32.2 |

| TBA | Total CVOCs | |
|---|---|---|
| ND | ND | --- |
| 4,300 | 87,277 | APS-08-24.6 |

| TBA | Total CVOCs | |
|---|---|---|
| 1,300 | 25 | APS-09-17 |
| 2,100 | 13,914 | APS-09-22 |
| 7,100 | 8,320 | APS-09-26.3 |




**Environmental Resources Management**

Figure 2-7
Zone of Significant Mass: S1/C1 Interface
French Limited Superfund Site
Crosby, Texas

| | | |
|---|---|---|
| DESIGN: ST | DRAWN: EFC | CHKD.: |
| DATE: 3/3/2014 | SCALE: AS SHOWN | REV.: |

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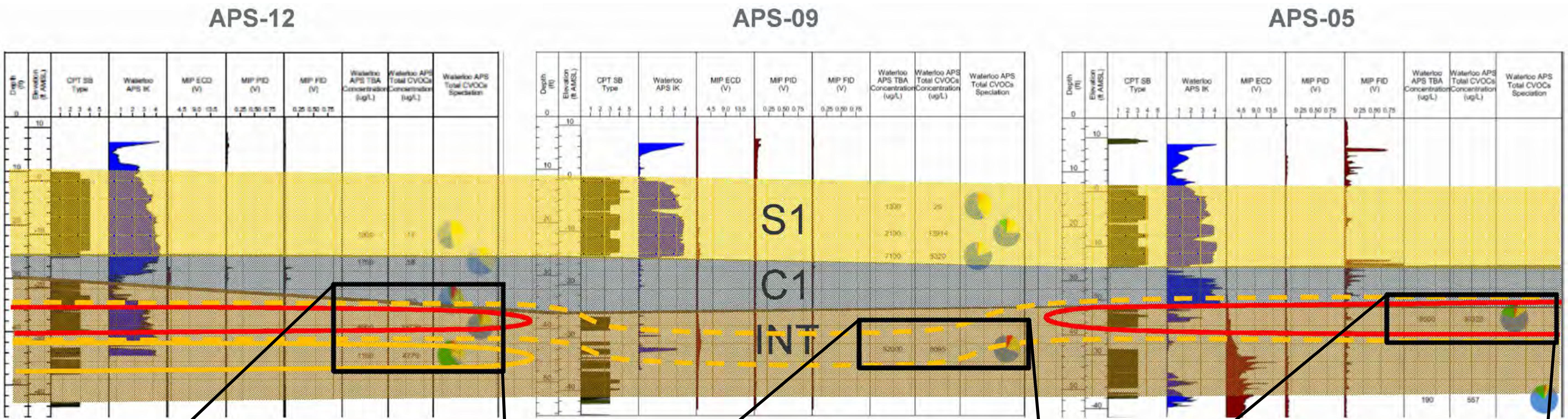
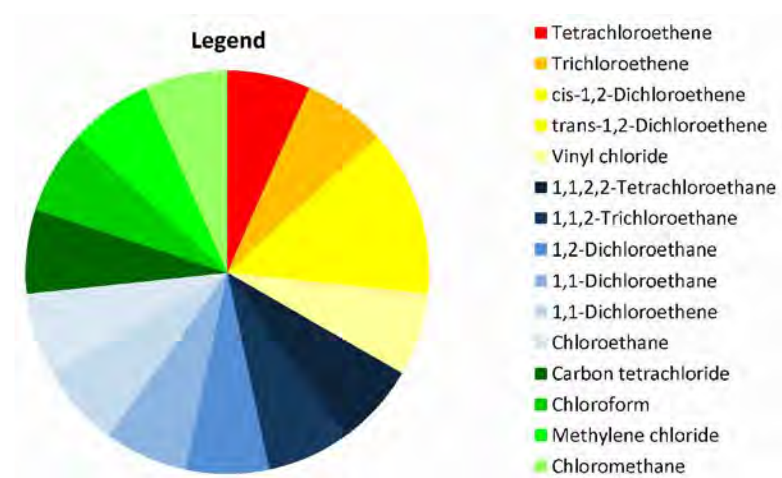



| TBA | Total CVOCs | Sample |
|---|---|---|
| 86 | 250 | APS-12-34.3 |
| 8,000 | 13,739 | APS-12-39.1 |
| 1,100 | 4,779 | APS-12-44.5 |

| TBA | Total CVOCs | Sample |
|---|---|---|
| 82,000 | 8,095 | APS-09-43.9 |

| TBA | Total CVOCs | Sample |
|---|---|---|
| 8,500 | 30,328 | APS-05-37 |




Total CVOC Concentrations (ug/L)

10,000

1,000

**Environmental Resources Management**

Figure 2-8
Zone of Significant Mass: INT Facies
French Limited Superfund Site
Crosby, Texas

| DESIGN: ST | DRAWN: EFC | CHKD.: |
|---|---|---|
| DATE: 3/3/2014 | SCALE: AS SHOWN | REV.: |

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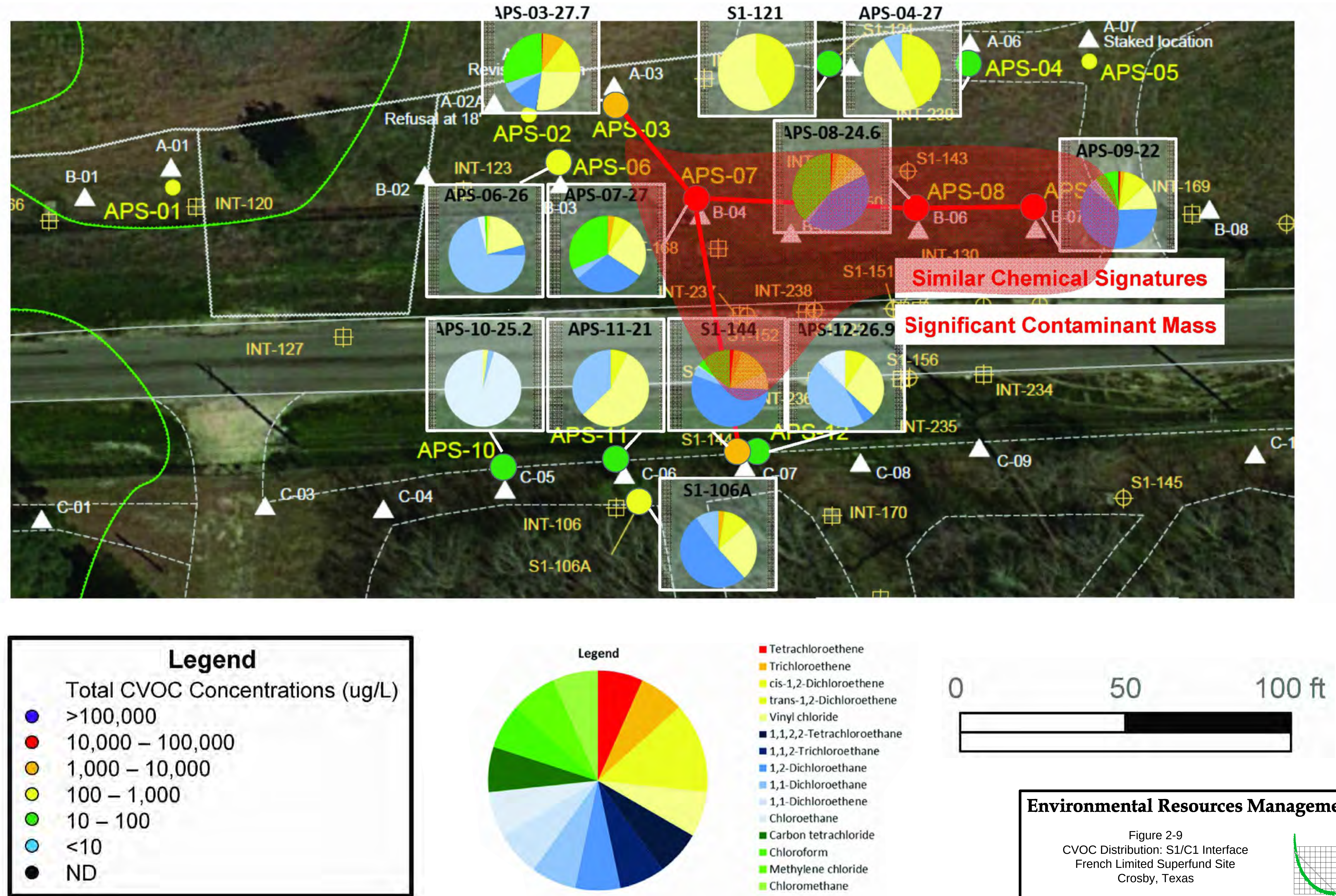
ERM-Southwest, Inc. TX PE Firm No. 2393




**Environmental Resources Management**

Figure 2-9
CVOC Distribution: S1/C1 Interface
French Limited Superfund Site
Crosby, Texas

| DESIGN: ST | DRAWN: EFC | CHKD.: |
|---|---|---|
| DATE: 3/3/2014 | SCALE: AS SHOWN | REV.: |

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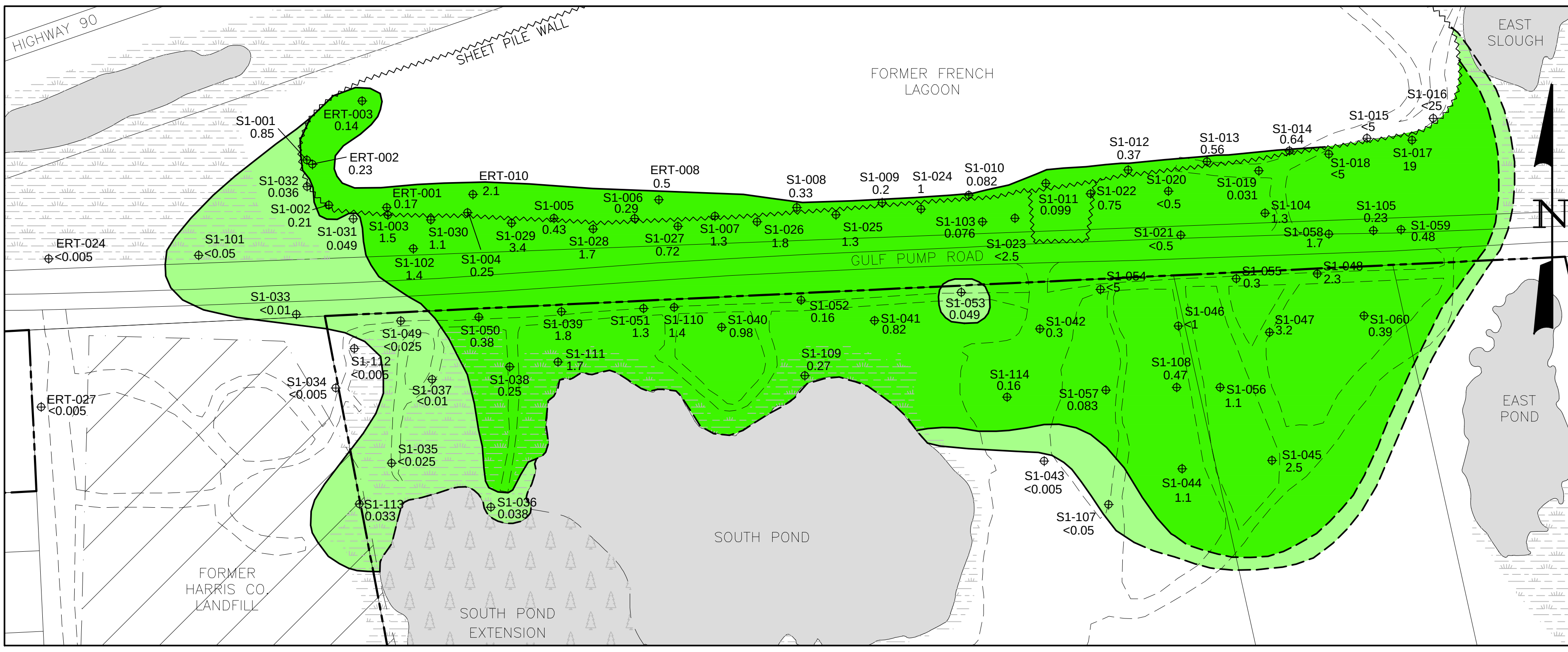
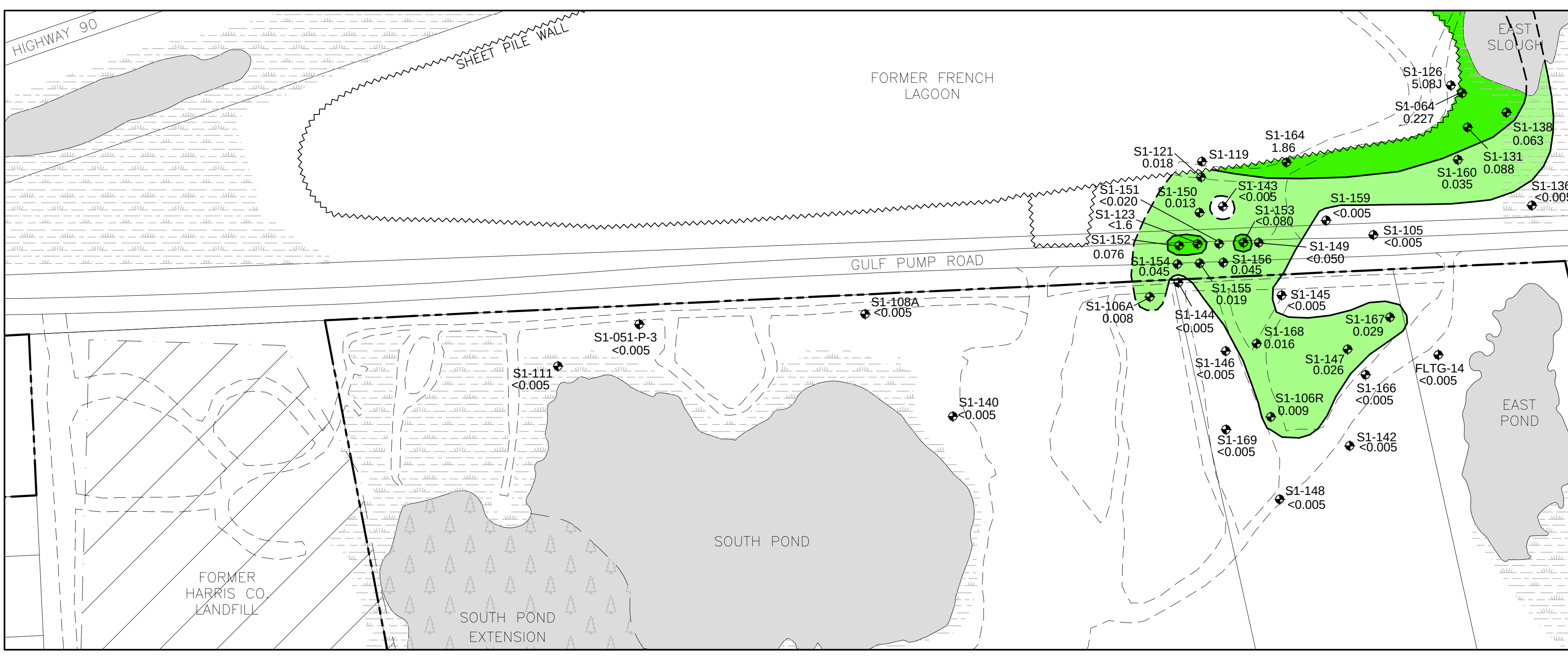
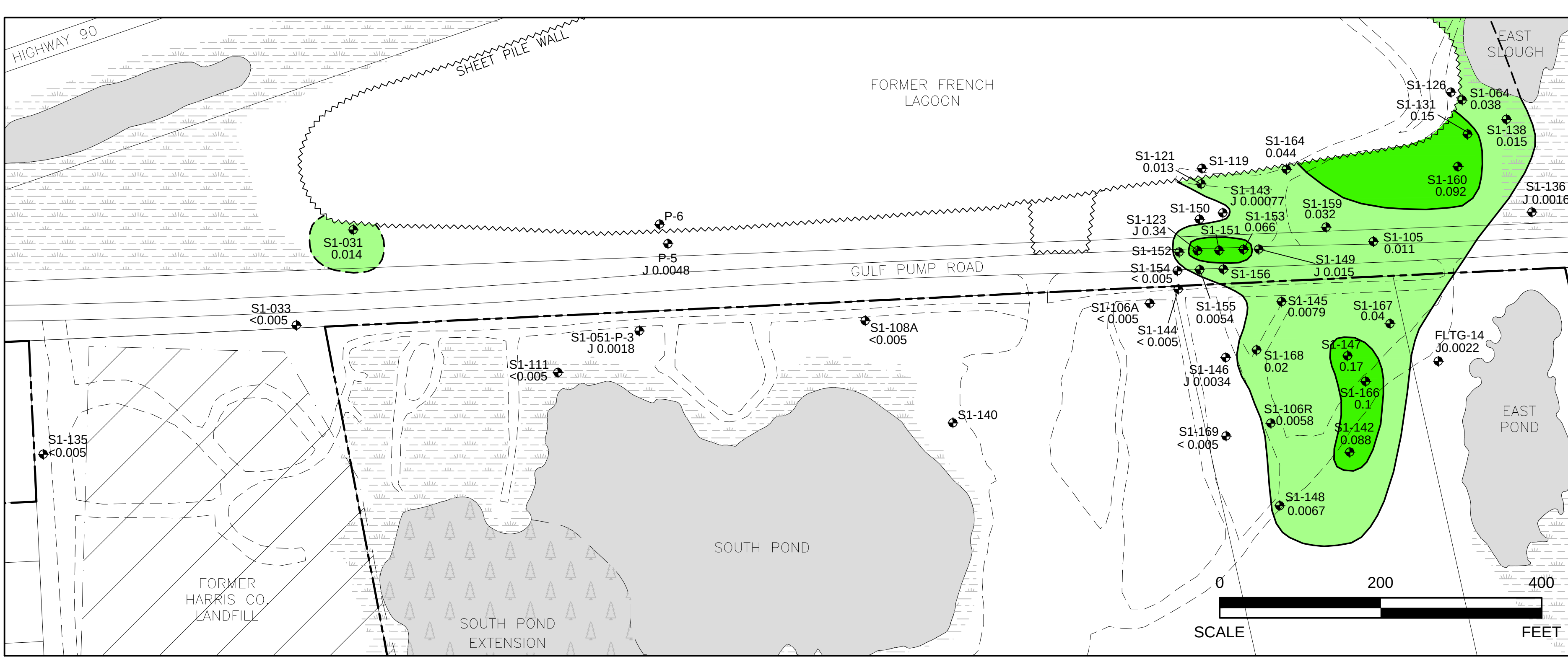



## 1991 PRE-ACTIVE REMEDIATION




## 2004




## 2013 POST-MONITORED NATURAL ATTENUATION

LEGEND

- S1 WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- FLTG PROPERTY BOUNDARY
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD

BENZENE IN GROUNDWATER

- ≥0.005 mg/L
- ≥0.05 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

**Environmental Resources Management**

FIGURE 3-1
BENZENE IN GROUND WATER
S1 UNIT (1991, 2004 and 2013)
French Limited Superfund Site
Crosby, Texas

ERM

| DESIGN: | DRAWN: | CHKD.: |
|---|---|---|
| DATE: 3/31/2014 | SCALE: AS SHOWN | REV.: |

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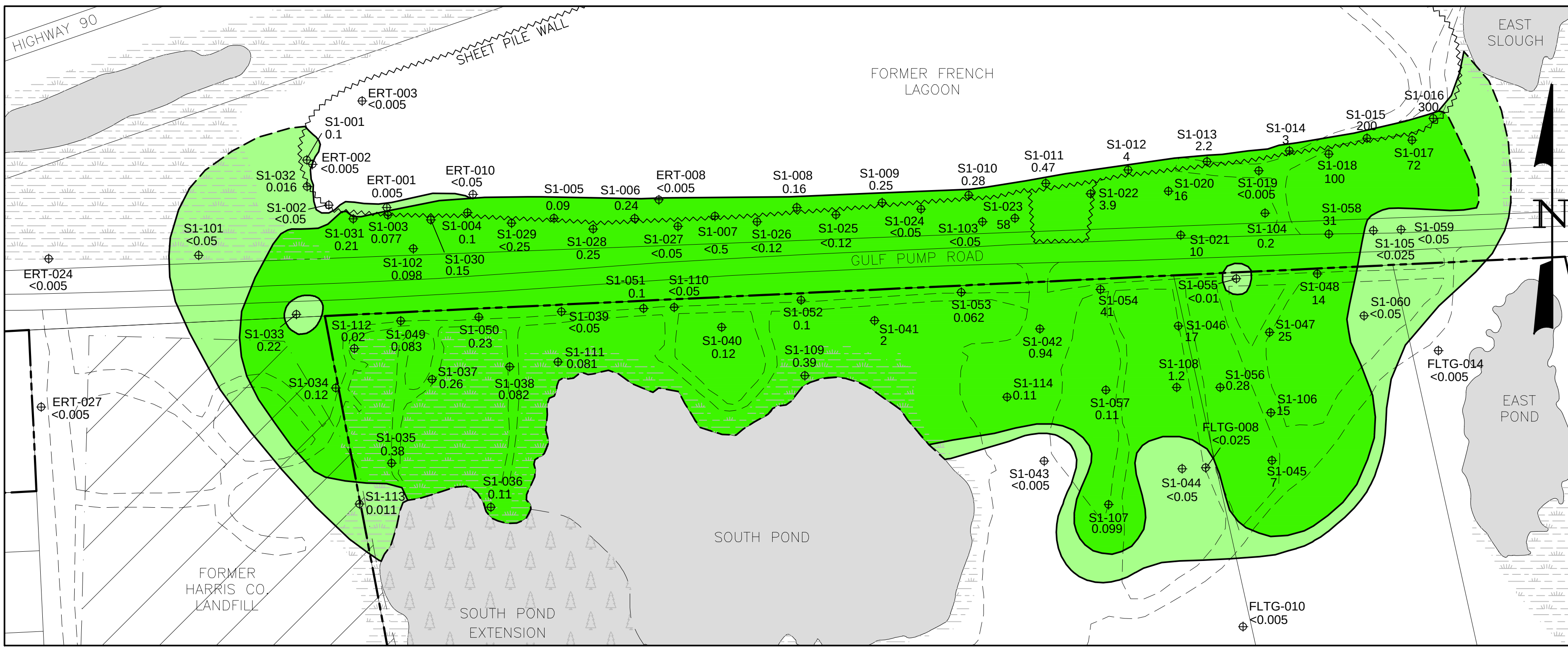
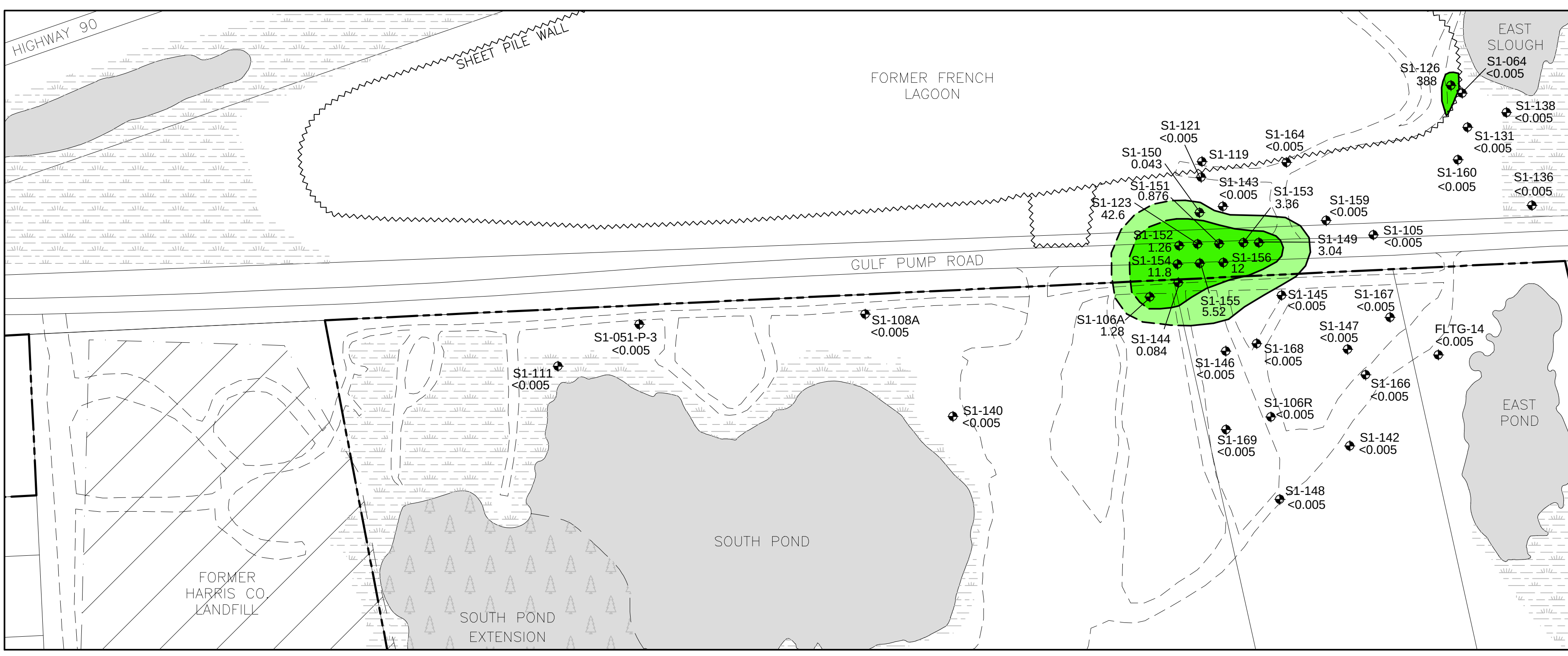
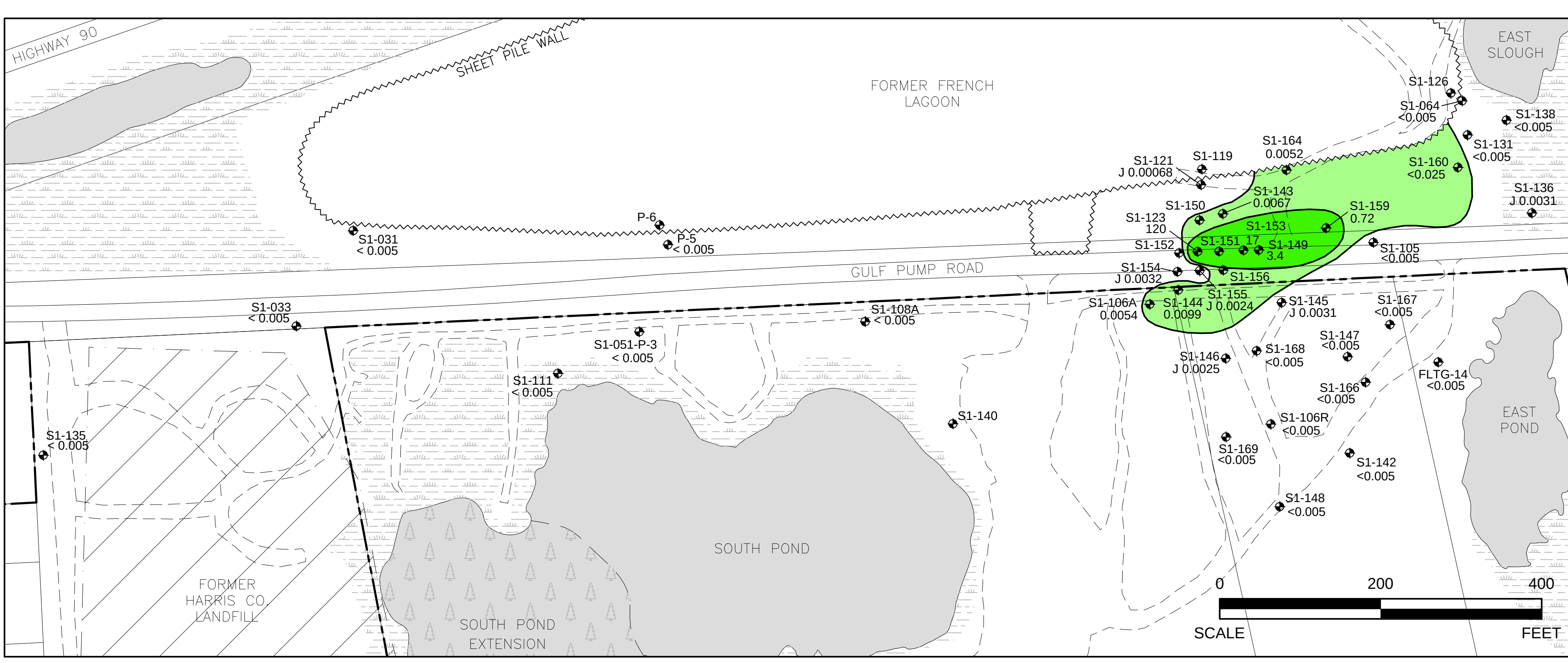
ERM-Southwest, Inc. TX PE Firm No. 2393




## 1991 PRE-ACTIVE REMEDIATION




## 2004




## 2013 POST-MONITORED NATURAL ATTENUATION

LEGEND

- S1 WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- FLTG PROPERTY BOUNDARY
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD

1,2 DICHLOROETHANE IN GROUND WATER

- ≥0.005 mg/L
- ≥0.05 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

**Environmental Resources Management**

FIGURE 3-2
1,2 DICHLOROETHANE IN GROUND WATER
S1 UNIT (1991, 2004 and 2013)
French Limited Superfund Site
Crosby, Texas

| DESIGN: R. Jaros | DRAWN: EFC | CHKD.: |
|---|---|---|
| DATE: 3/31/2014 | SCALE: AS SHOWN | REV.: |

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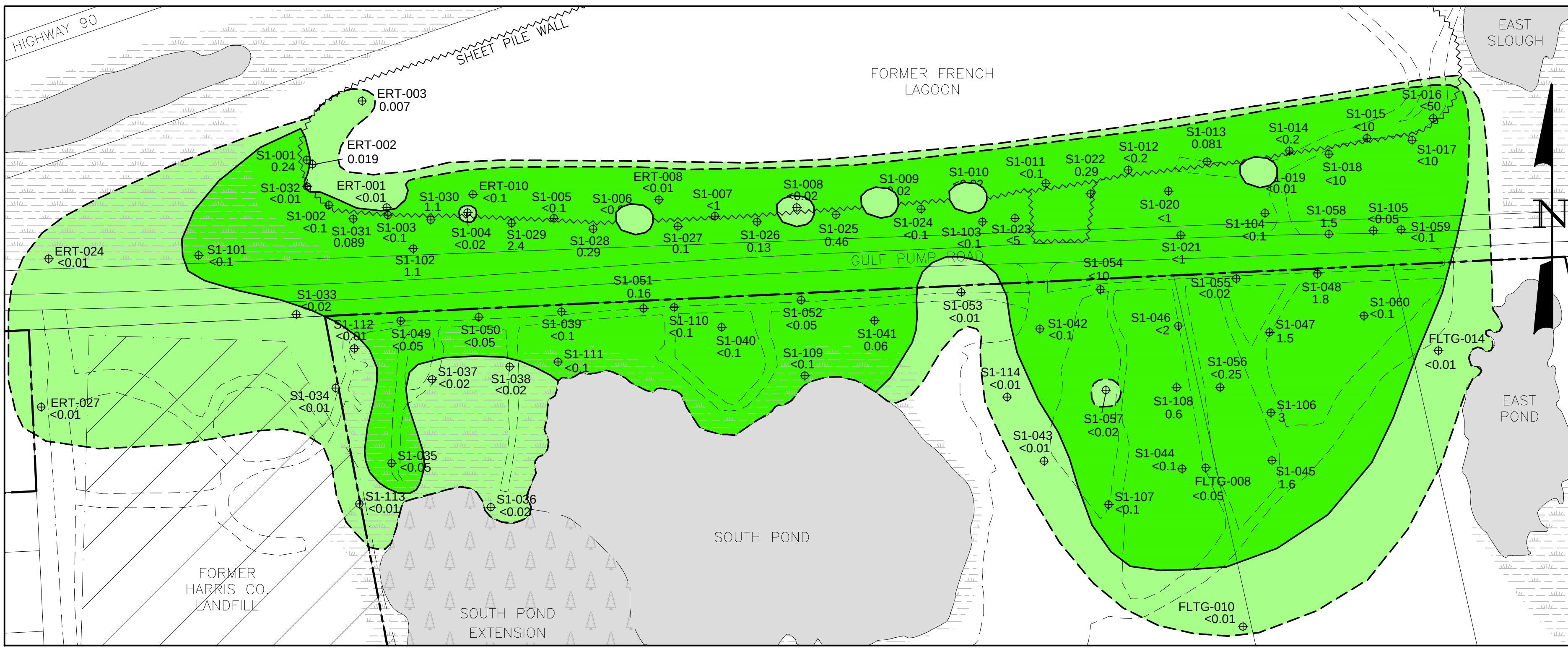
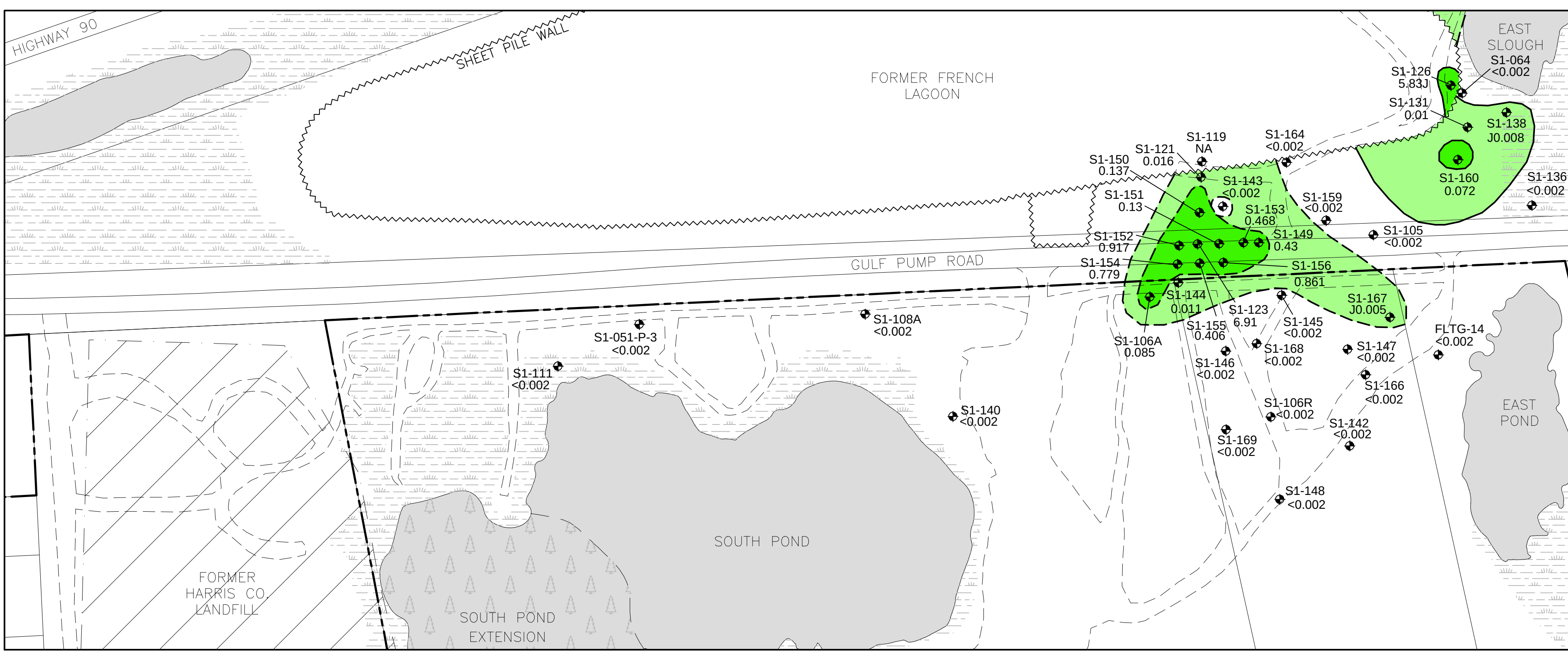
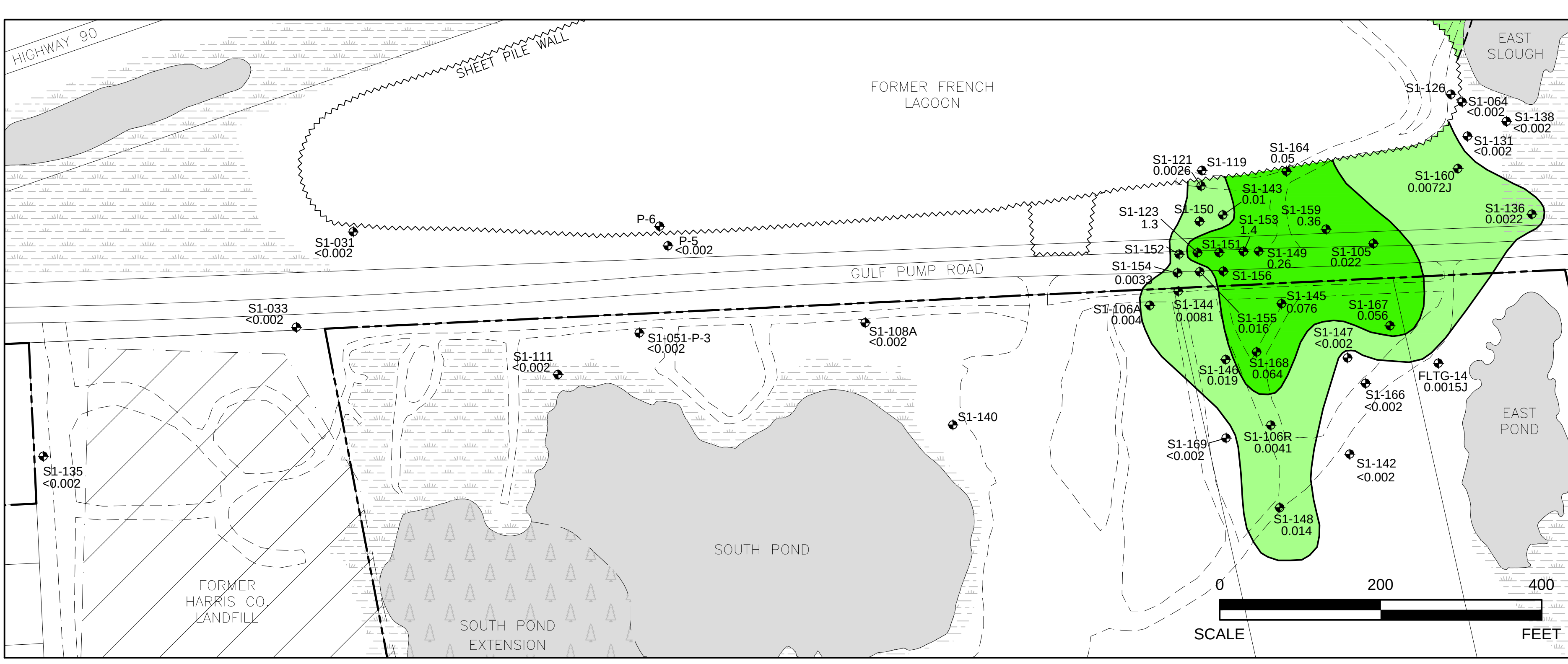



## 1991 PRE-ACTIVE REMEDIATION




## 2004




## 2013 POST-MONITORED NATURAL ATTENUATION

LEGEND

- S1 WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- FLTG PROPERTY BOUNDARY
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD

VINYL CHLORIDE IN GROUNDWATER

- ≥0.002 mg/L
- ≥0.02 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

**Environmental Resources Management**

FIGURE 3-3
VINYL CHLORIDE IN GROUND WATER
S1 UNIT (1991, 2004 and 2013)
French Limited Superfund Site
Crosby, Texas

| DESIGN: | DRAWN: | CHKD.: |
|---|---|---|
| DATE: 3/31/2014 | SCALE: AS SHOWN | REV.: |

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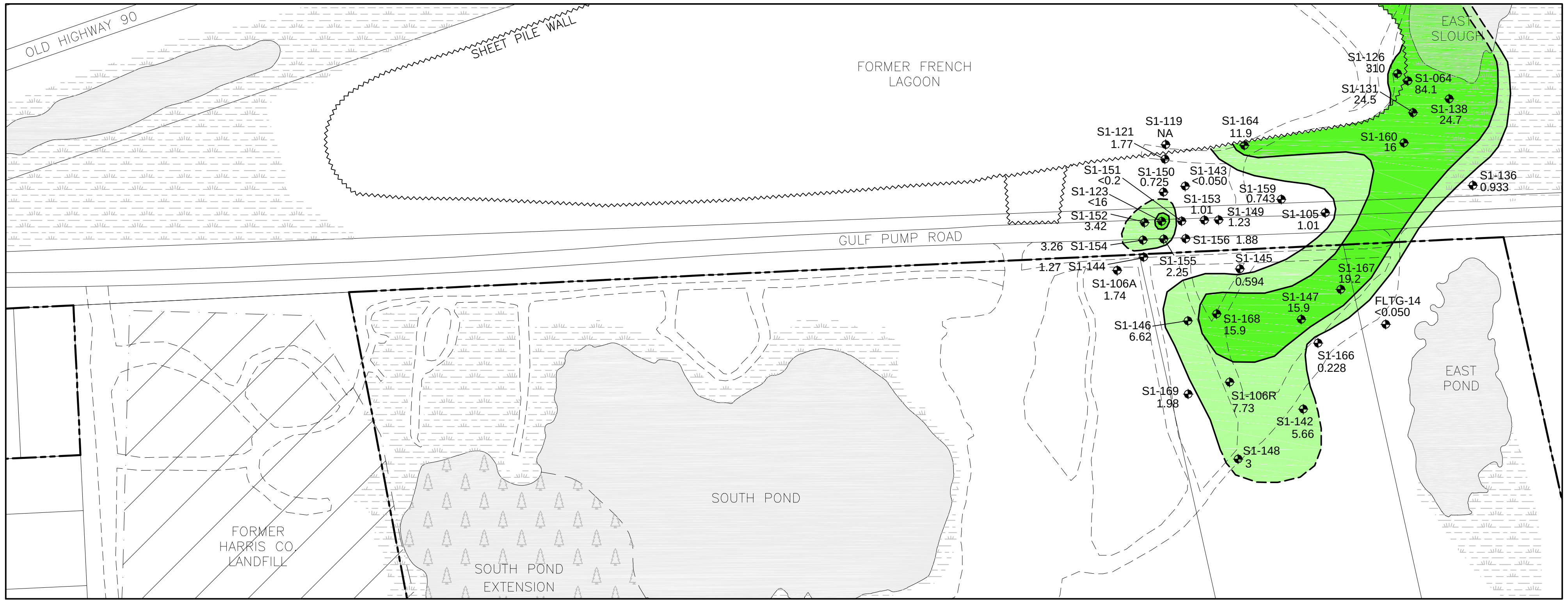
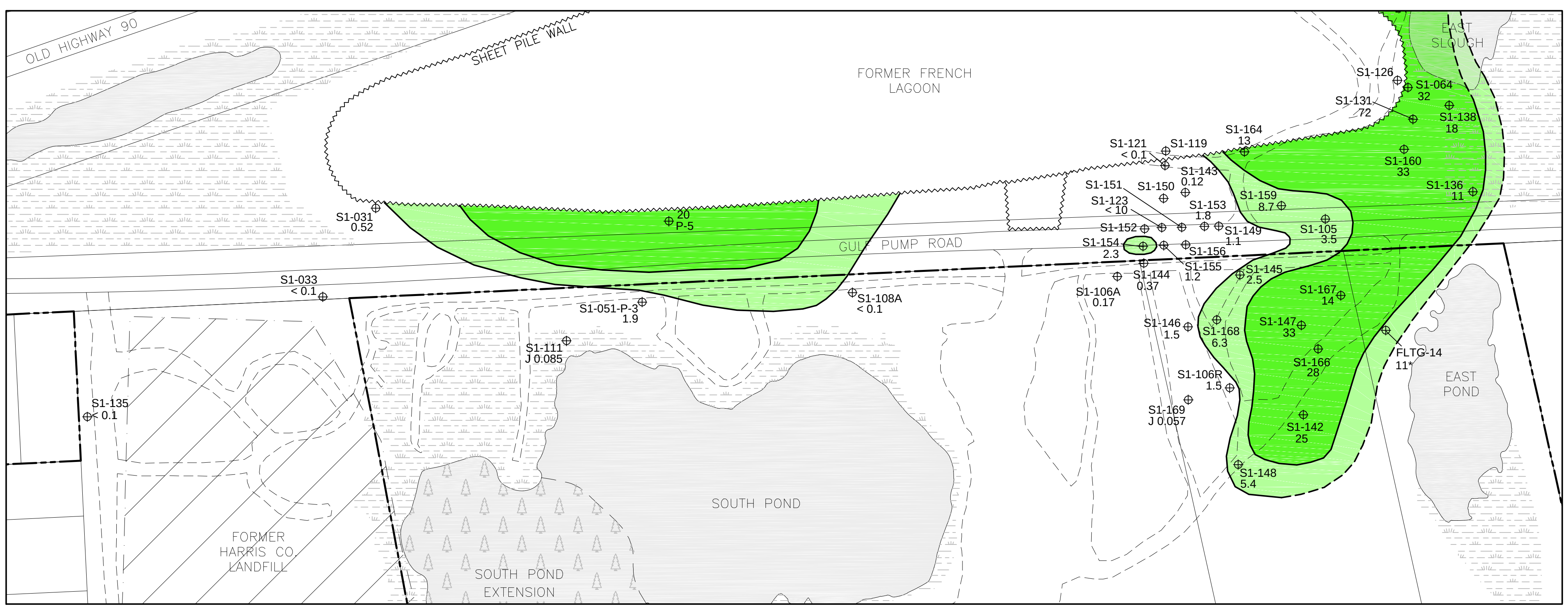
ERM-Southwest, Inc. TX PE Firm No. 2393




**2004**




**2013**

N

LEGEND

- S1 WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD
- FLTG PROPERTY BOUNDARY

TERTIARY-BUTYL ALCOHOL IN GROUNDWATER

- ≥2.2 mg/L
- ≥10 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

0 200 400

SCALE FEET

**Environmental Resources Management**

FIGURE 3-4
TERTIARY-BUTYL ALCOHOL IN GROUND WATER
S1 UNIT (2004 vs. 2013)
French Limited Superfund Site
Crosby, Texas

| | | |
|---|---|---|
| DESIGN: S. Tomashitis | DRAWN: EFC | CHKD.: |
| DATE: 3/26/2014 | SCALE: AS SHOWN | REV.: |

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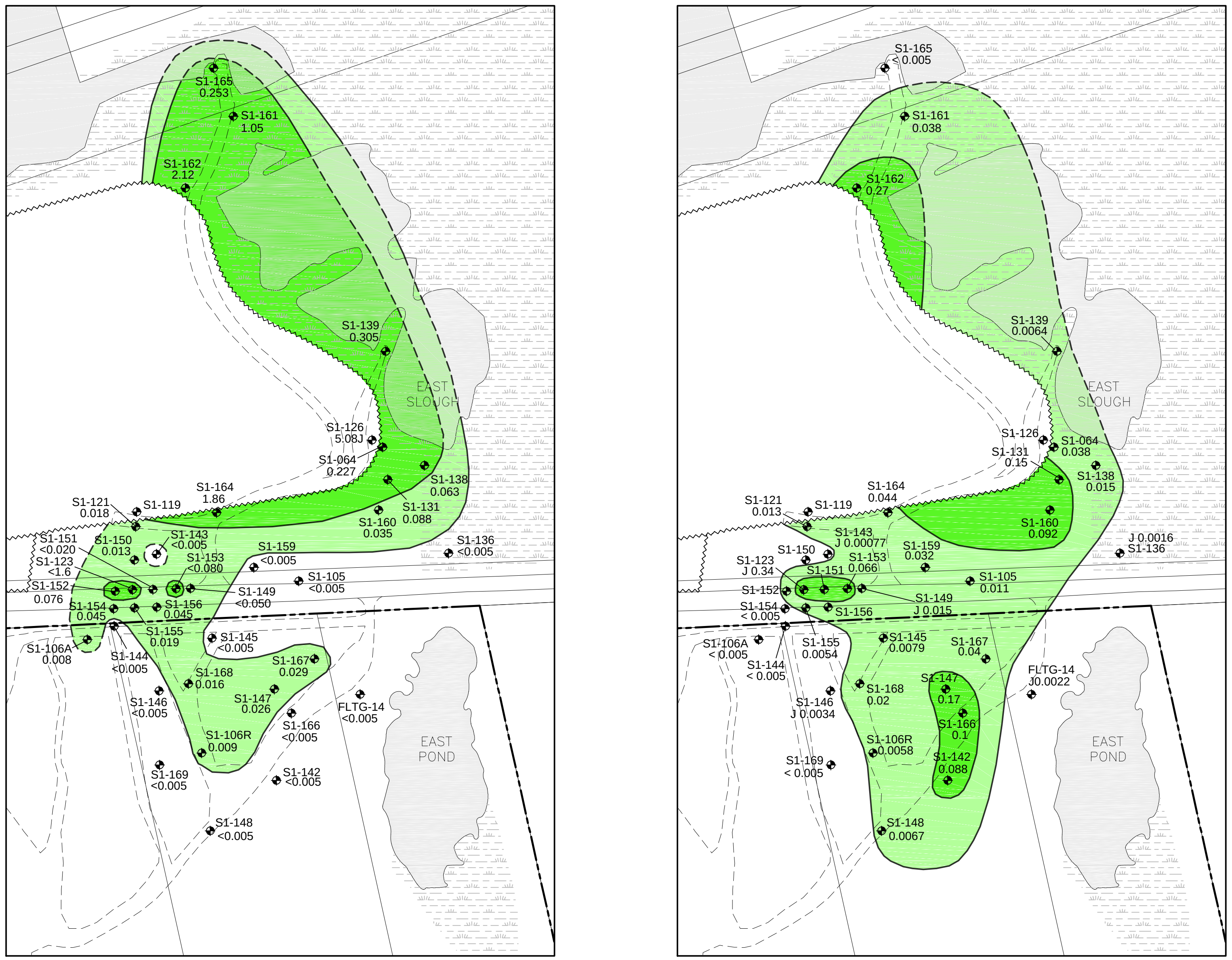
ERM

ERM-Southwest, Inc. TX PE Firm No. 2393




**2004** **2013**

N

LEGEND

- S1 WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD
- FLTG PROPERTY BOUNDARY

BENZENE IN GROUNDWATER

- ≥0.005 mg/L
- ≥0.05 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

0 200 400

SCALE FEET

**Environmental Resources Management**

FIGURE 3-5
BENZENE IN GROUND WATER
CENTRAL AND EAST PLUME AREAS - S1 UNIT (2004 vs. 2013)
French Limited Superfund Site
Crosby, Texas

ERM

| DESIGN: S. Tomashitis | DRAWN: EFC | CHKD.: |
|---|---|---|
| DATE: 3/6/2014 | SCALE: AS SHOWN | REV.: |

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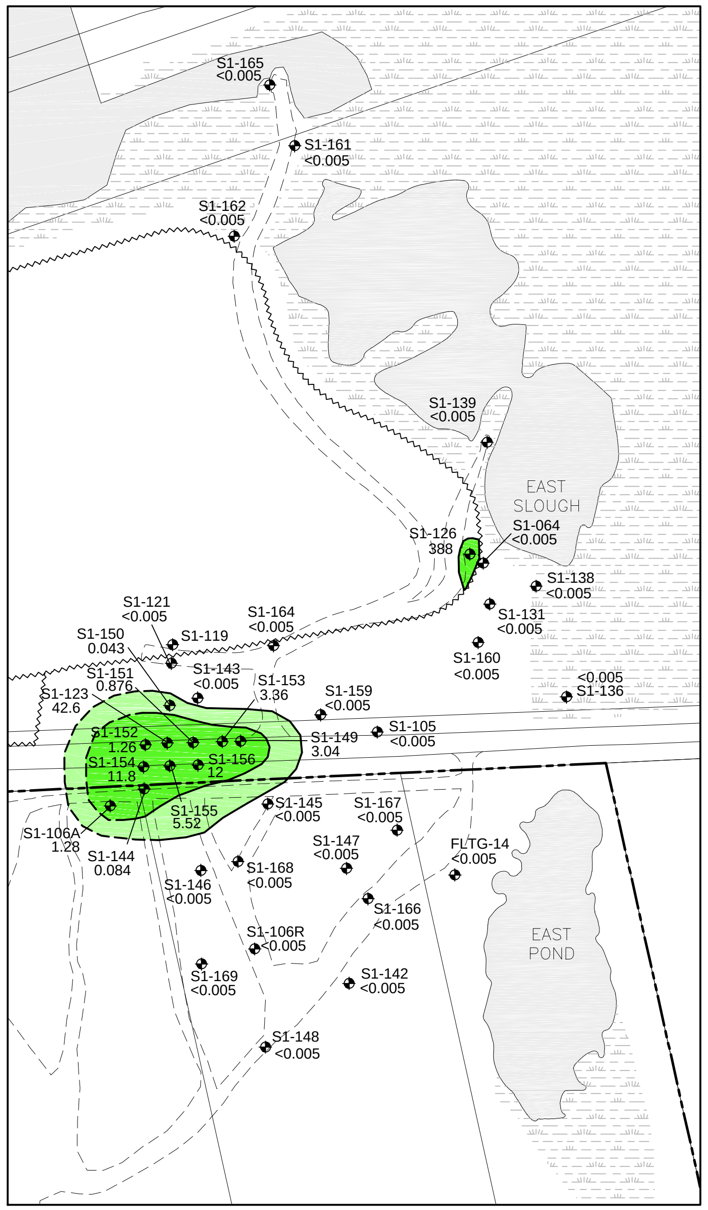
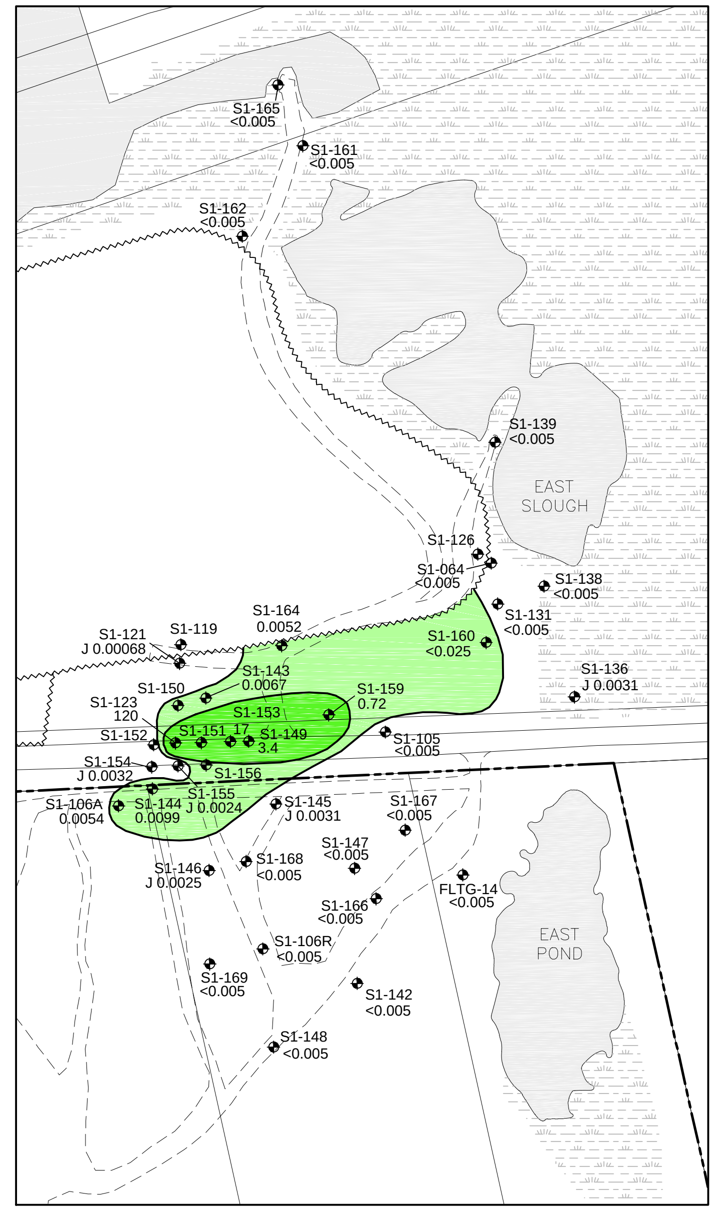
ERM-Southwest, Inc. TX PE Firm No. 2393




**2004**




**2013**

N

LEGEND

S1 WELL

0.524 CONSTITUENT CONCENTRATION (mg/L)

<0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)

NA SAMPLE NOT ANALYZED FOR CONSTITUENT

SWAMP AND/OR WETLAND

CYPRESS SWAMP

POND OR LAKE

SHEET PILE WALL

PAVED ROAD

UNPAVED ROAD

FLTG PROPERTY BOUNDARY

1,2 DICHLOROETHANE IN GROUNDWATER

≥0.005 mg/L

≥0.05 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

0 200 400

SCALE FEET

**Environmental Resources Management**

FIGURE 3-6
1,2 DICHLOROETHANE IN GROUND WATER
CENTRAL AND EAST PLUME AREAS - S1 UNIT (2004 vs. 2013)
French Limited Superfund Site
Crosby, Texas

ERM

| | | |
|---|---|---|
| DESIGN: S. Tomashitis | DRAWN: EFC | CHKD.: |
| DATE: 3/6/2014 | SCALE: AS SHOWN | REV.: |

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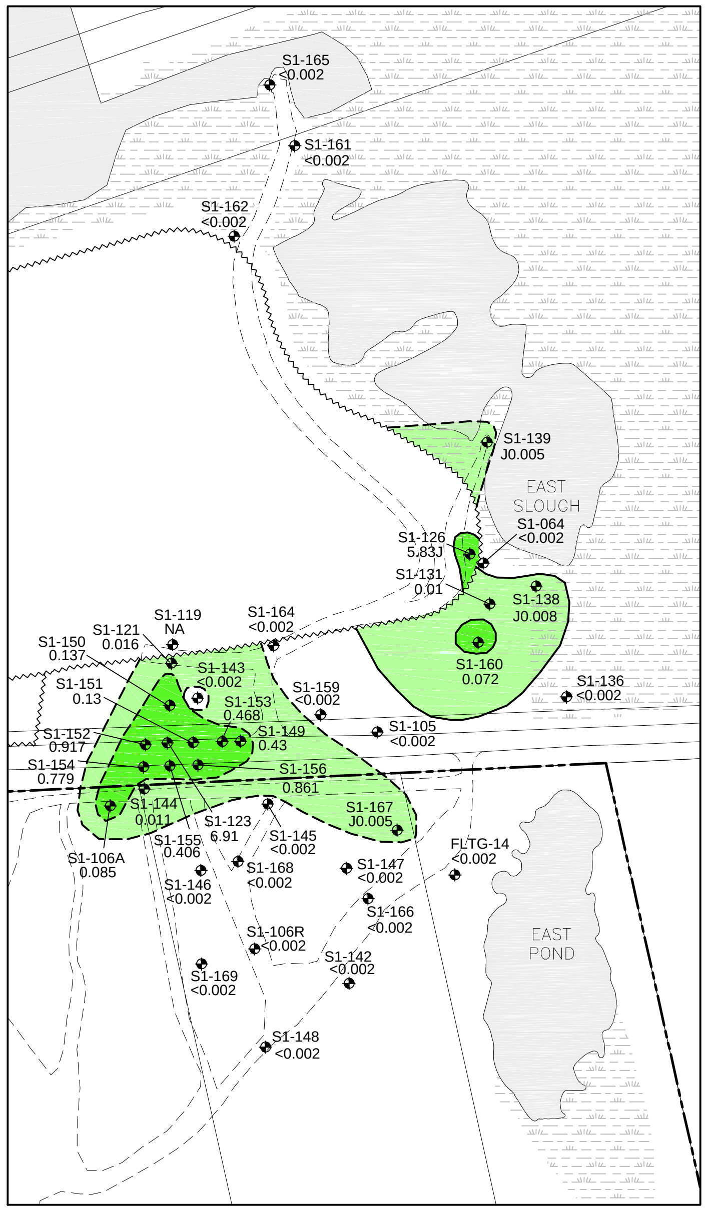
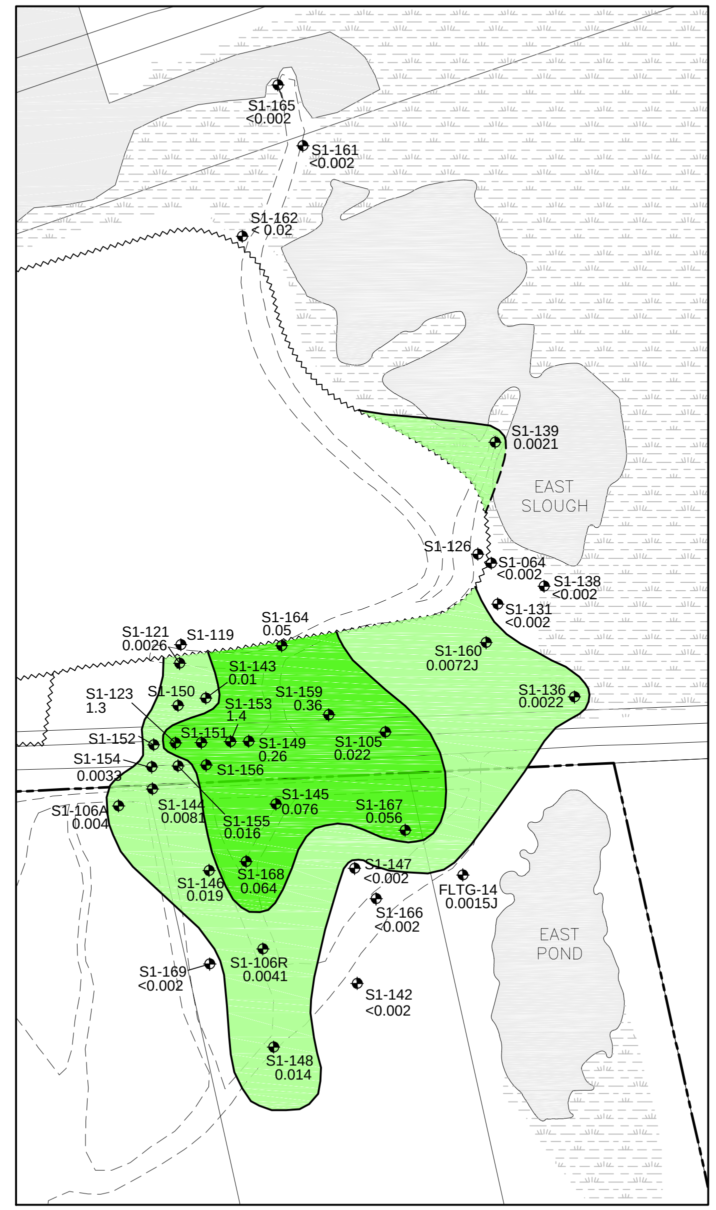
ERM-Southwest, Inc. TX PE Firm No. 2393




## 2004




## 2013

N

LEGEND

- S1 WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD
- FLTG PROPERTY BOUNDARY

VINYL CHLORIDE IN GROUNDWATER

- ≥0.002 mg/L
- ≥0.02 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

0 200 400

SCALE FEET

**Environmental Resources Management**

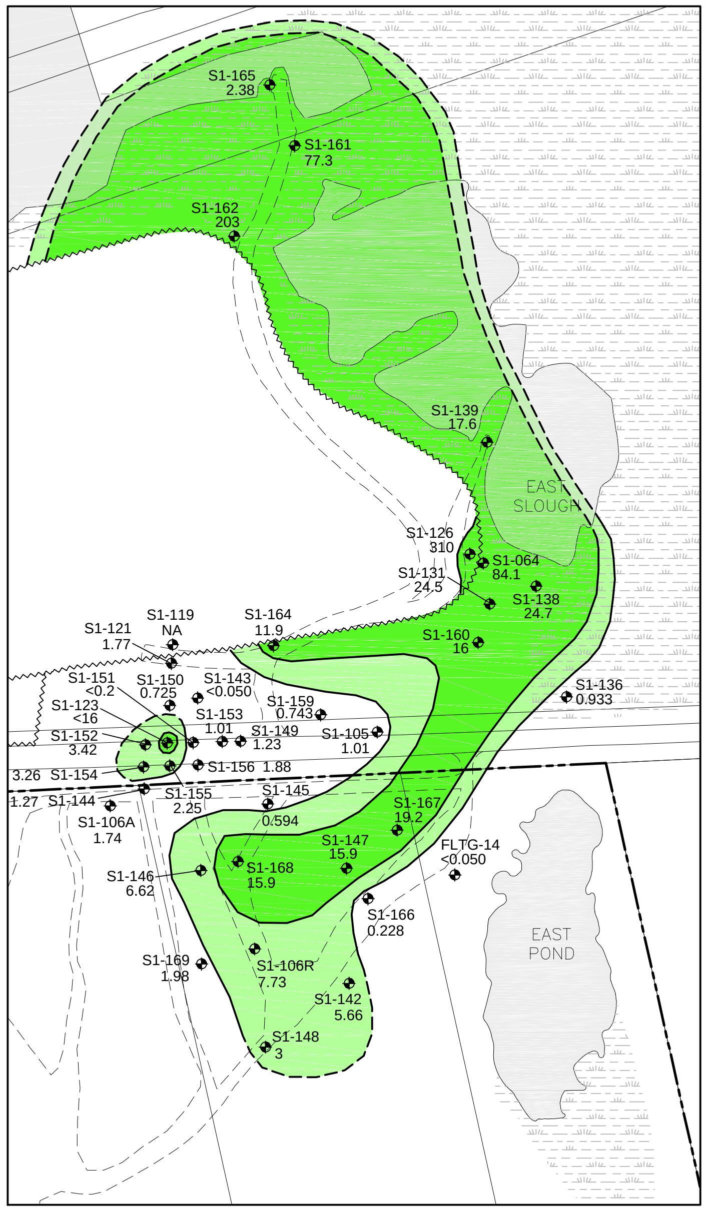
FIGURE 3-7
VINYL CHLORIDE IN GROUND WATER
CENTRAL AND EAST PLUME AREAS - S1 UNIT (2004 vs. 2013)
French Limited Superfund Site
Crosby, Texas

ERM

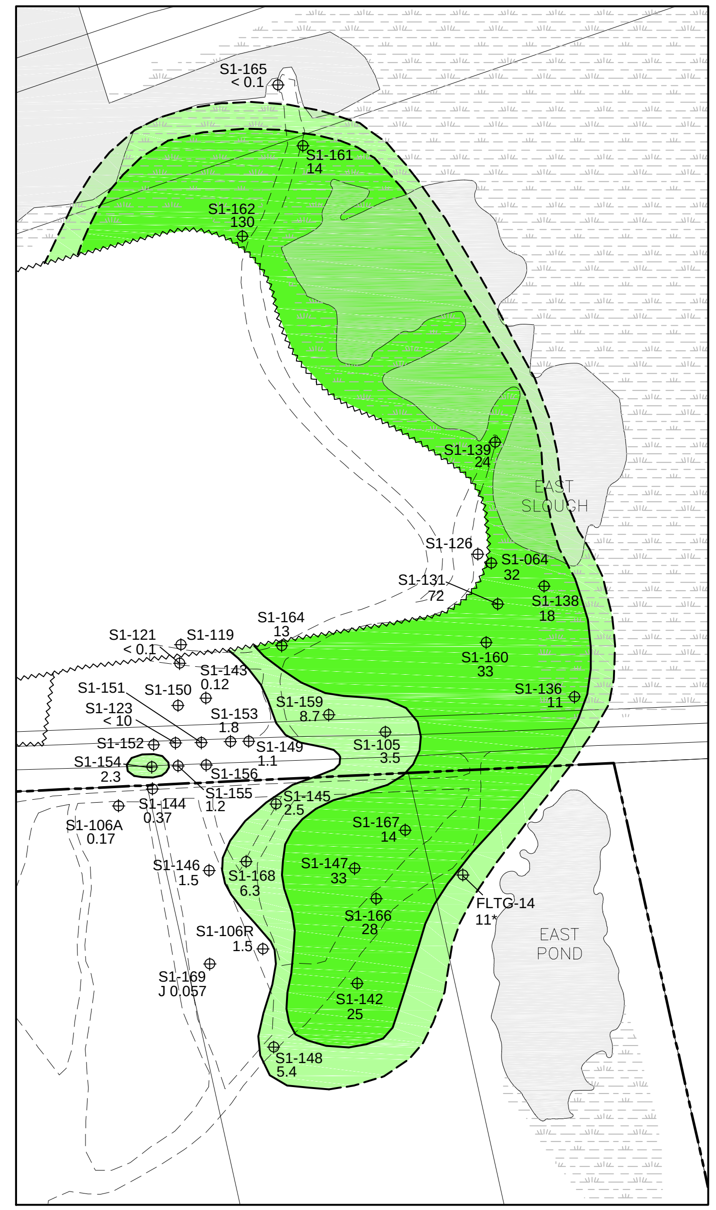
| DESIGN: S. Tomashitis | DRAWN: EFC | CHKD.: |
|---|---|---|
| DATE: 3/6/2014 | SCALE: AS SHOWN | REV.: |

W.O.NO.: H:\DWG\C14\FrenchLtd\0234672_VC_S1_East_5.dwg , 3/6/2014 10:27:25 AM

ERM-Southwest, Inc. TX PE Firm No. 2393




**2004**




**2013**

N

LEGEND

S1 WELL

0.524 CONSTITUENT CONCENTRATION (mg/L)

<0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)

NA SAMPLE NOT ANALYZED FOR CONSTITUENT

SWAMP AND/OR WETLAND

CYPRESS SWAMP

POND OR LAKE

SHEET PILE WALL

PAVED ROAD

UNPAVED ROAD

FLTG PROPERTY BOUNDARY

TERTIARY-BUTYL ALCOHOL IN GROUNDWATER

≥2.2 mg/L

≥10 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

0 200 400

SCALE FEET

**Environmental Resources Management**

FIGURE 3-8
TERTIARY-BUTYL ALCOHOL IN GROUND WATER
CENTRAL AND EAST PLUME AREAS - S1 UNIT (2004 vs. 2013)
French Limited Superfund Site
Crosby, Texas

ERM

| | | |
|---|---|---|
| DESIGN: S. Tomashitis | DRAWN: EFC | CHKD.: |
| DATE: 3/10/2014 | SCALE: AS SHOWN | REV.: |

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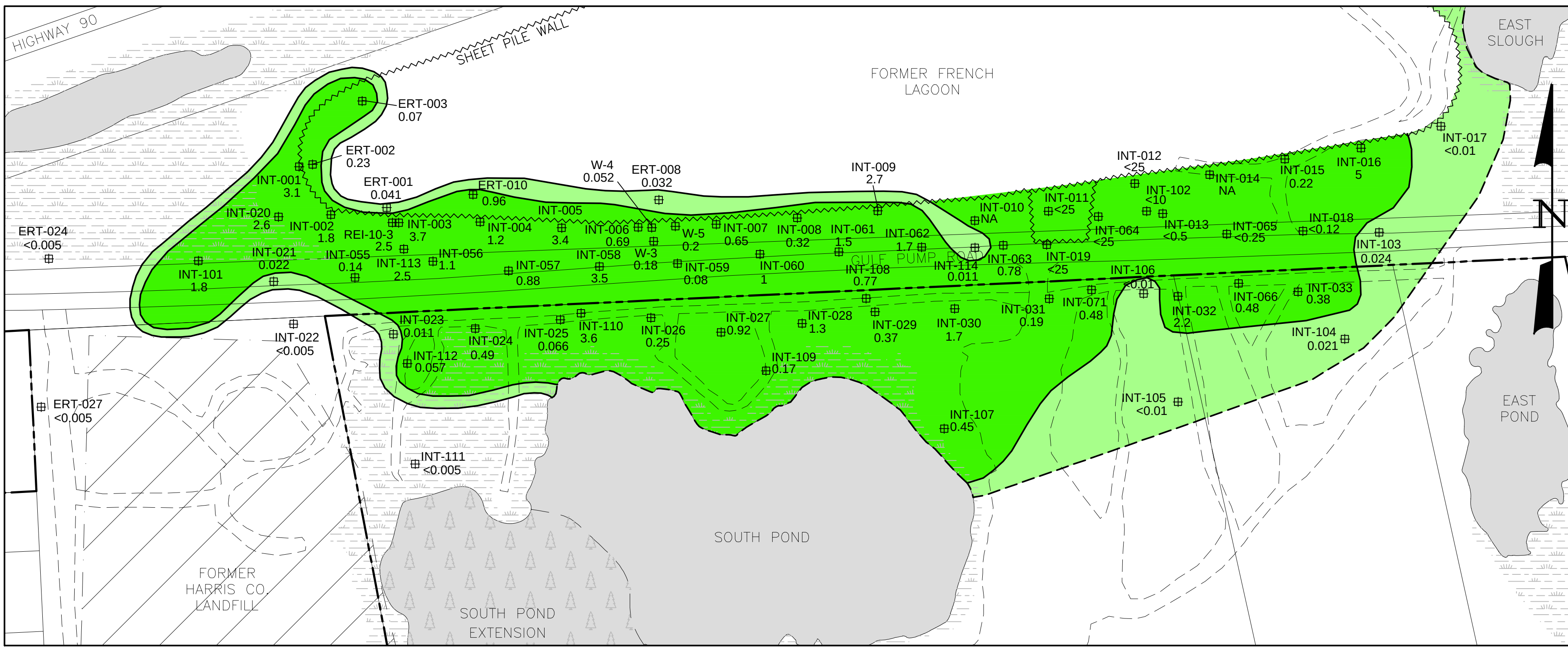
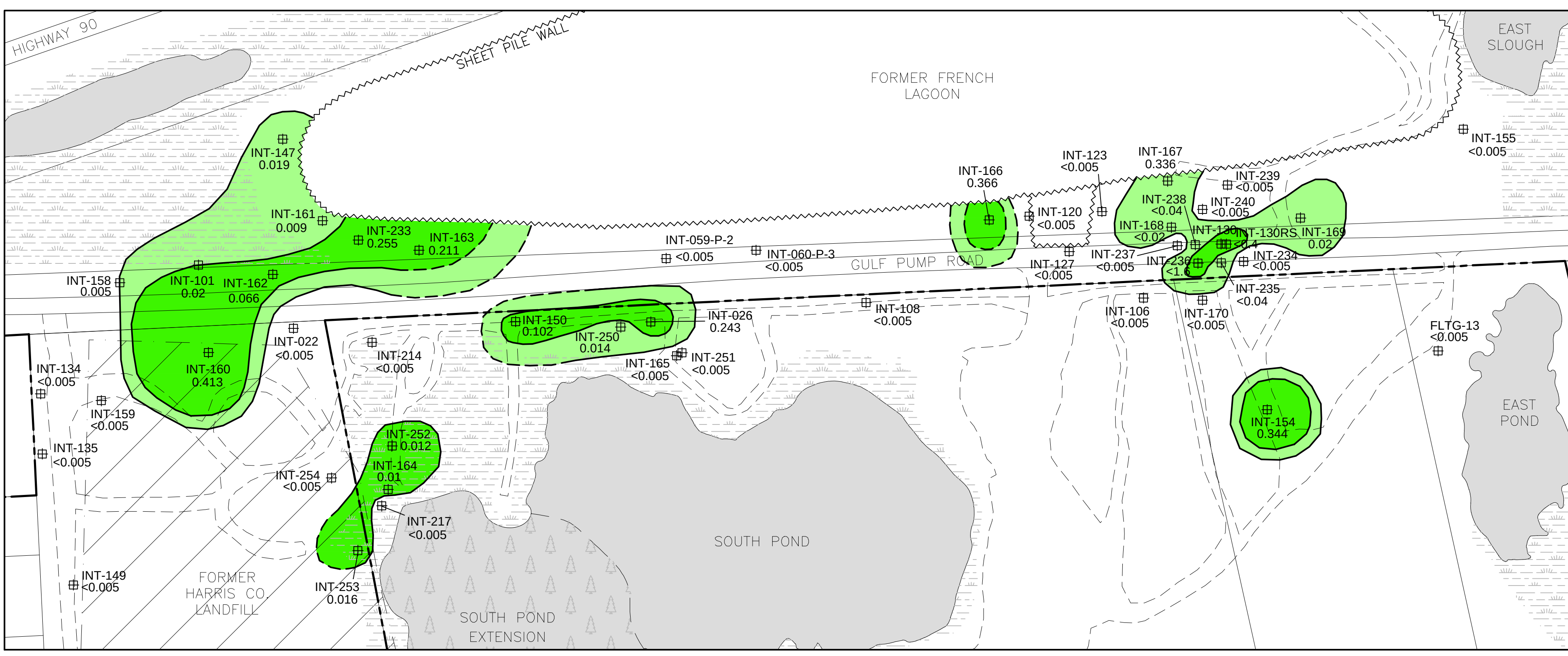
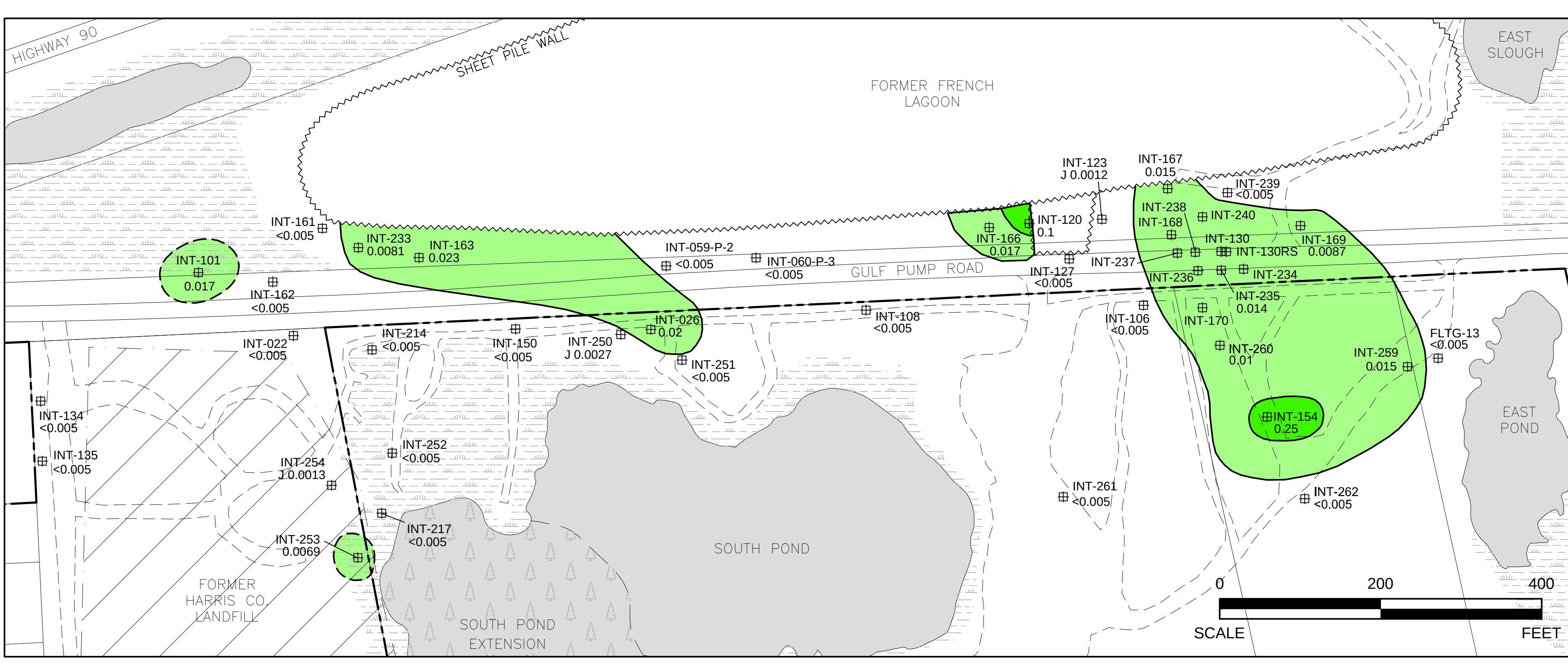
ERM-Southwest, Inc. TX PE Firm No. 2393




## 1991 PRE-ACTIVE REMEDIATION




## 2004




## 2013 POST-MONITORED NATURAL ATTENUATION

LEGEND

- INT WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- FLTG PROPERTY BOUNDARY
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD

BENZENE IN GROUNDWATER

- ≥0.005 mg/L
- ≥0.05 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

**Environmental Resources Management**

FIGURE 3-9
BENZENE IN GROUND WATER
INT UNIT (1991, 2004 and 2013)
French Limited Superfund Site
Crosby, Texas

ERM

| | | |
|---|---|---|
| DESIGN: R. Jaros | DRAWN: EFC | CHKD.: |
| DATE: 3/31/2014 | SCALE: AS SHOWN | REV.: |

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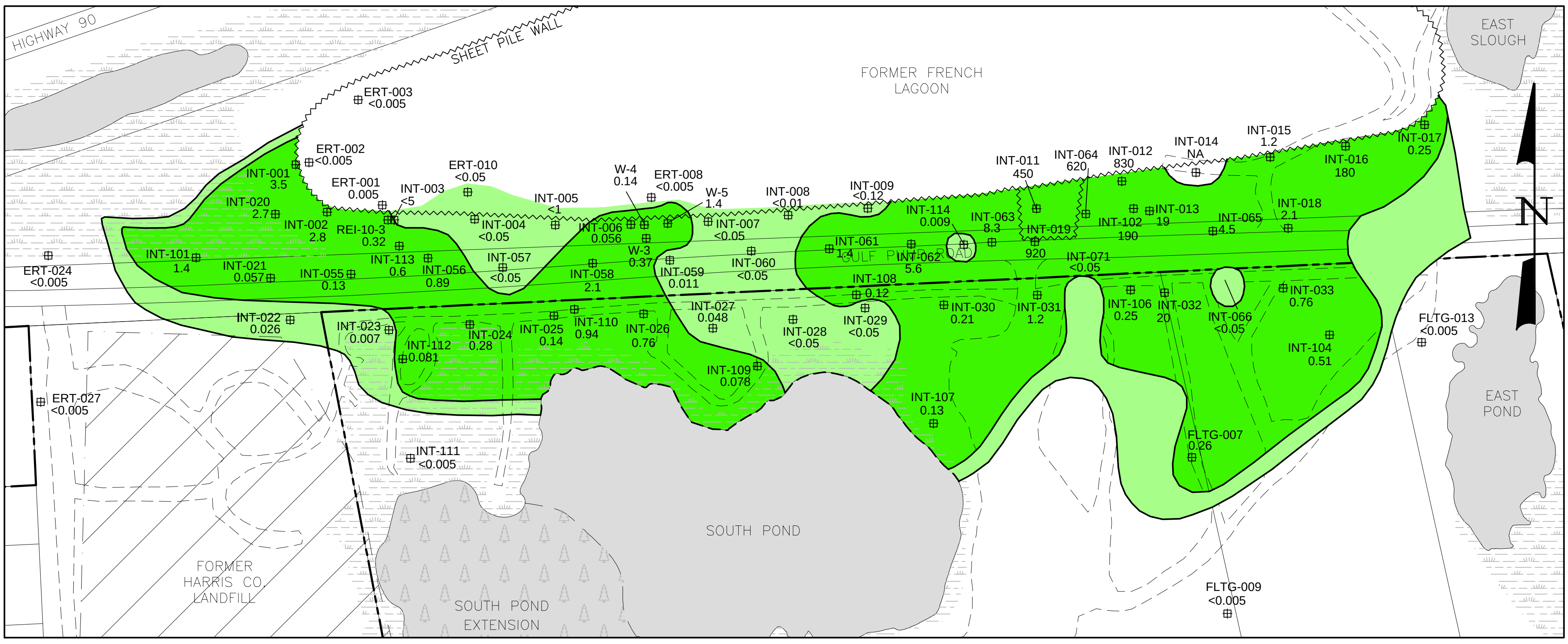
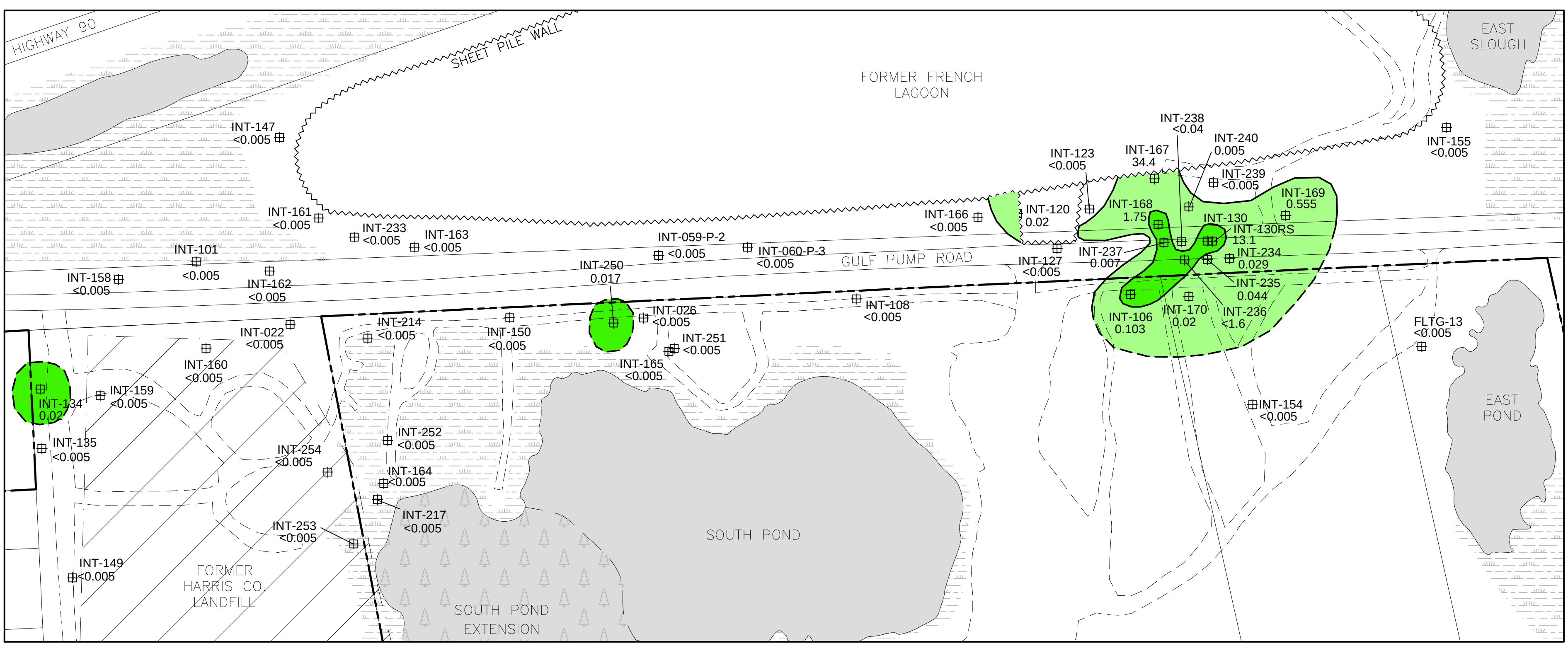
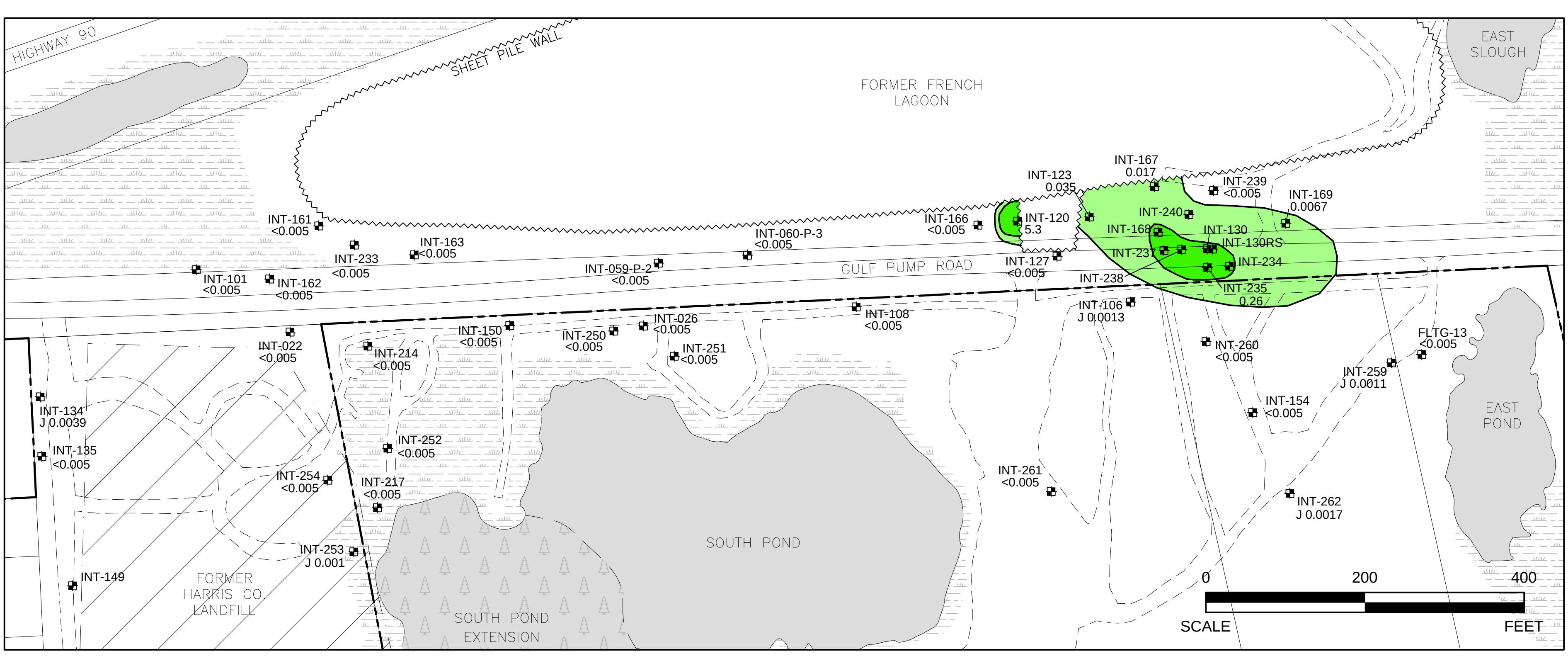
ERM-Southwest, Inc. TX PE Firm No. 2393




## 1991 PRE-ACTIVE REMEDIATION




## 2004




## 2013 POST-MONITORED NATURAL ATTENUATION

LEGEND

- INT WELL
- 0.524 CONSTITUENT CONCENTRATION (mg/L)
- <0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)
- NA SAMPLE NOT ANALYZED FOR CONSTITUENT
- FLTG PROPERTY BOUNDARY
- SWAMP AND/OR WETLAND
- CYPRESS SWAMP
- POND OR LAKE
- SHEET PILE WALL
- PAVED ROAD
- UNPAVED ROAD

1,2 DICHLOROETHANE IN GROUNDWATER

- ≥0.005 mg/L
- ≥0.05 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

**Environmental Resources Management**

FIGURE 3-10
1,2 DICHLOROETHANE IN GROUND WATER
INT UNIT (1991, 2004 and 2013)
French Limited Superfund Site
Crosby, Texas

ERM

| | | |
|---|---|---|
| DESIGN: R. Jaros | DRAWN: EFC | CHKD.: |
| DATE: 3/31/2014 | SCALE: AS SHOWN | REV.: |

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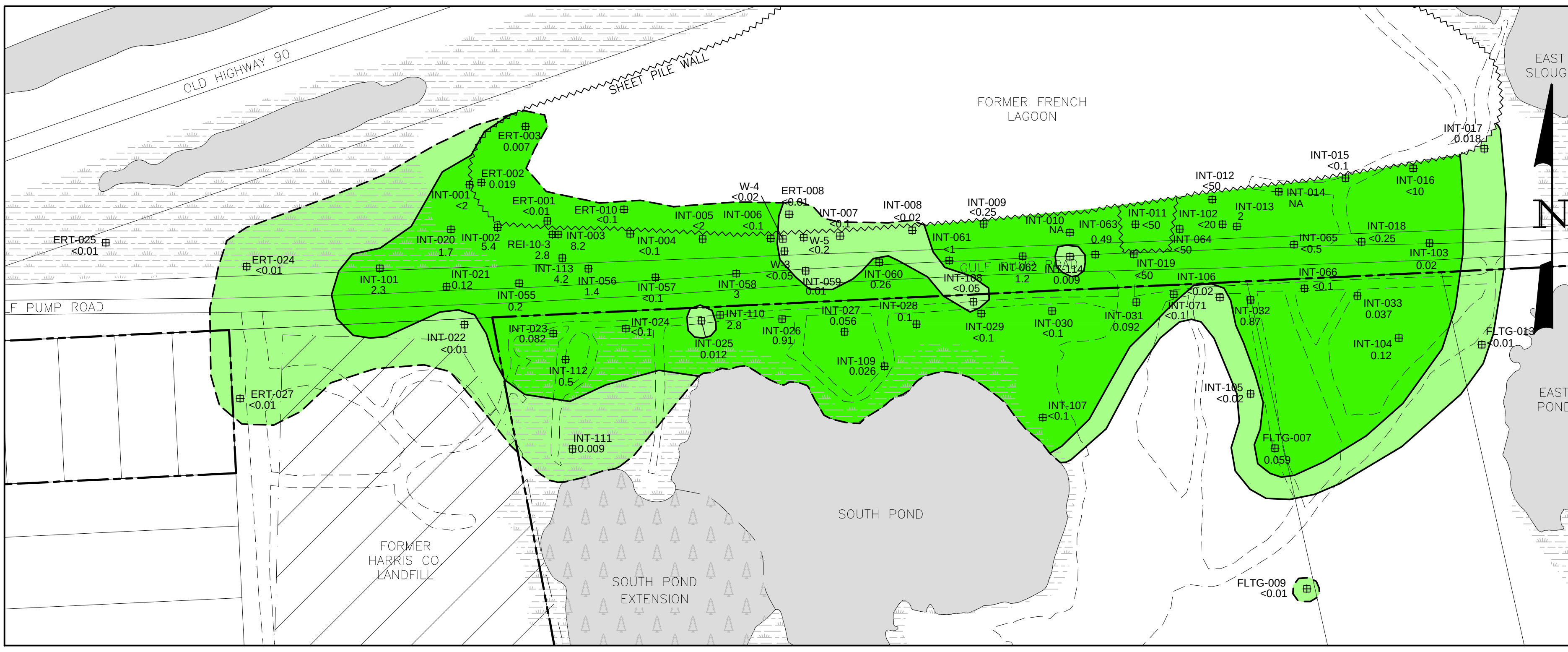
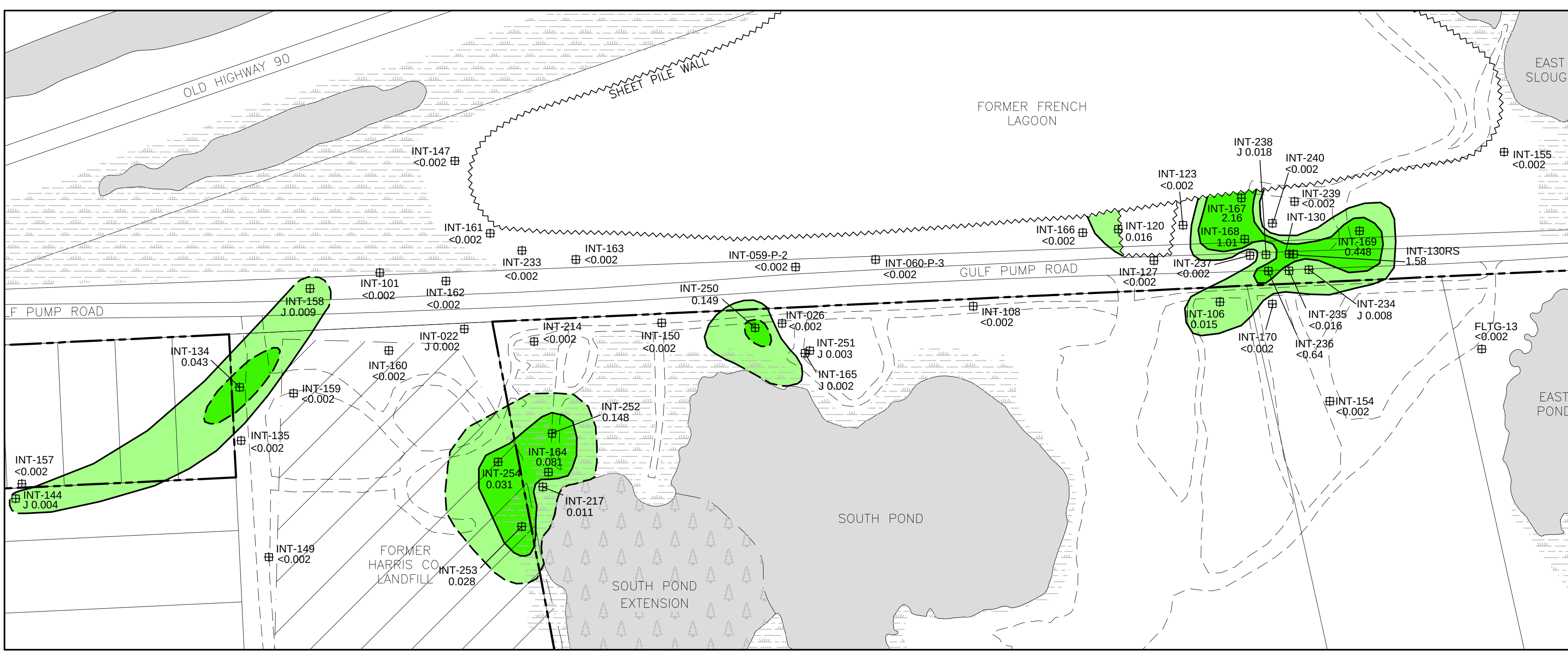
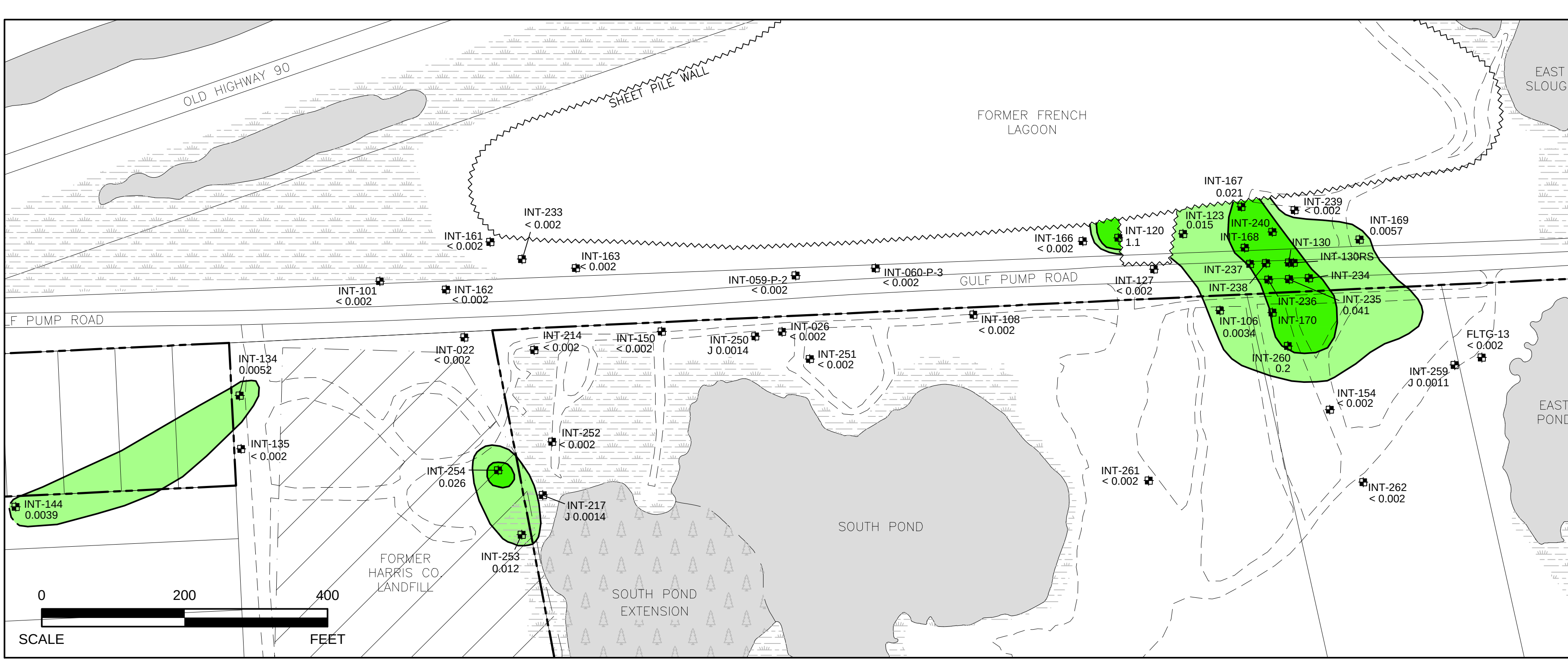
ERM-Southwest, Inc. TX PE Firm No. 2393




## 1991 PRE-ACTIVE REMEDIATION




## 2004




## 2013 POST-MONITORED NATURAL ATTENUATION

LEGEND

| | |
|---|---|
| ⊠ | INT WELL |
| 0.524 | CONSTITUENT CONCENTRATION (mg/L) |
| <0.005 | CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L) |
| NA | SAMPLE NOT ANALYZED FOR CONSTITUENT |
| | FLTG PROPERTY BOUNDARY |
| | SWAMP AND/OR WETLAND |
| | CYPRESS SWAMP |
| | POND OR LAKE |
| | SHEET PILE WALL |
| | PAVED ROAD |
| | UNPAVED ROAD |

VINYL CHLORIDE IN GROUNDWATER

- ≥0.002 mg/L
- ≥0.02 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

**Environmental Resources Management**

FIGURE 3-11
VINYL CHLORIDE IN GROUND WATER
INT UNIT (1991, 2004 and 2013)
French Limited Superfund Site
Crosby, Texas

ERM

| | | |
|---|---|---|
| DESIGN: R. Jaros | DRAWN: EFC | CHKD.: |
| DATE: 3/31/2014 | SCALE: AS SHOWN | REV.: |

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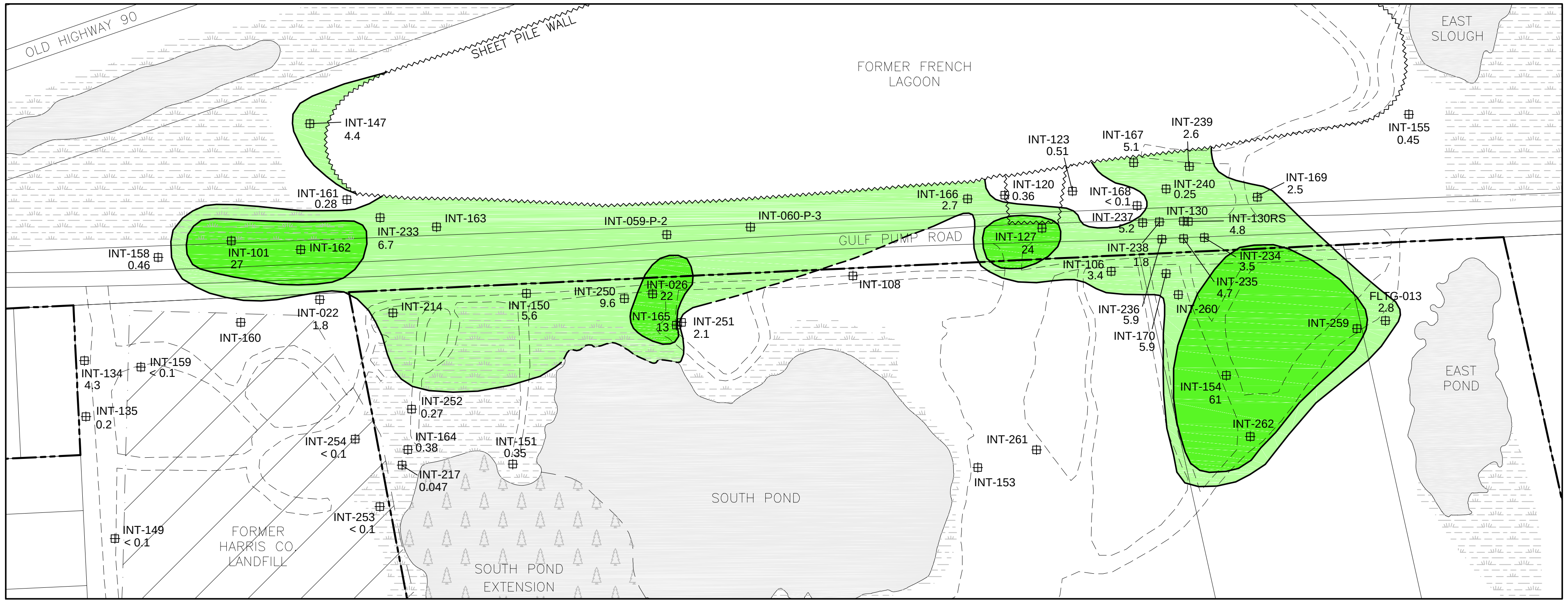
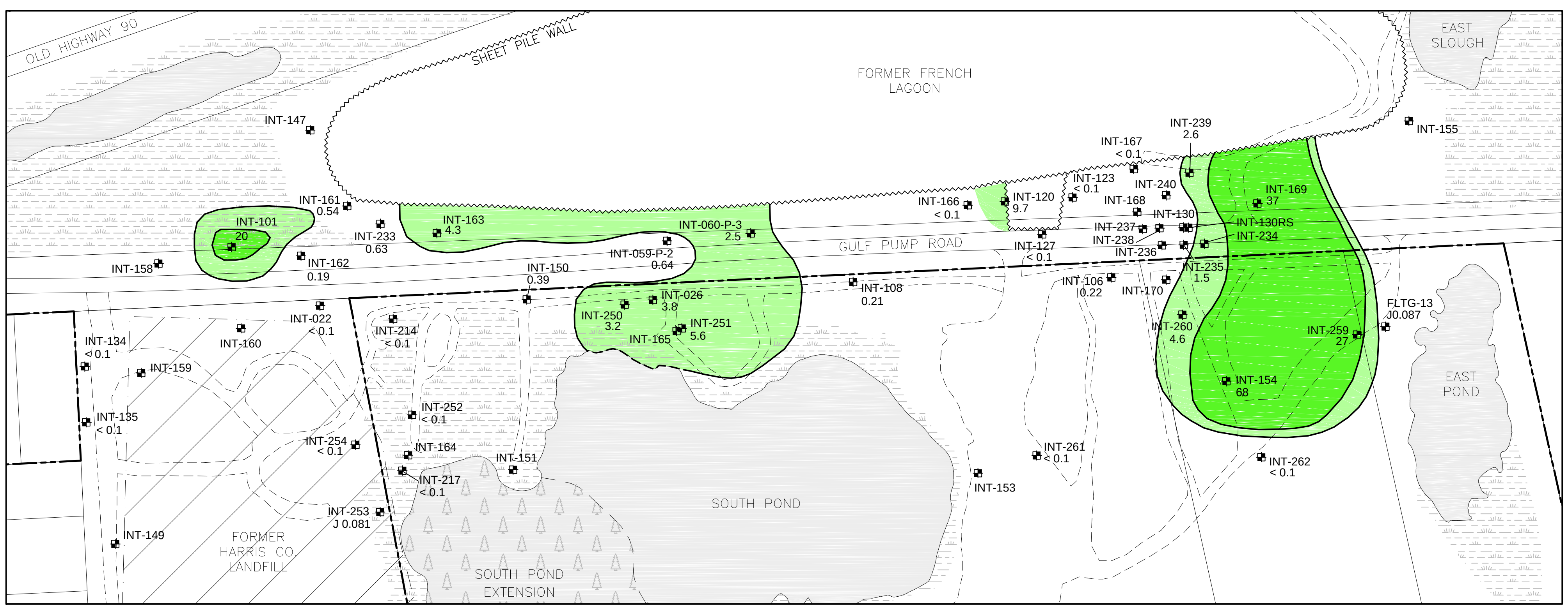



## 2002




## 2013

N

LEGEND

INT WELL

0.524 CONSTITUENT CONCENTRATION (mg/L)

<0.005 CONSTITUENT NOT DETECTED AT INDICATED DETECTION LIMIT (MG/L)

NA SAMPLE NOT ANALYZED FOR CONSTITUENT

SWAMP AND/OR WETLAND

CYPRESS SWAMP

POND OR LAKE

SHEET PILE WALL

PAVED ROAD

UNPAVED ROAD

FLTG PROPERTY BOUNDARY

TERTIARY-BUTYL ALCOHOL IN GROUNDWATER

≥2.2 mg/L

≥10 mg/L

DASHED WHERE INFERRED

NOTE: WELLS SHOWN WITH NO POSTED RESULTS WERE NOT SAMPLED DURING THIS MONITORING EVENT. WHERE THE REPORTED DETECTION LIMIT EXCEEDED THE RAO, THE DETECTION LIMIT WAS USED FOR CONTOURING.

0 200 400

SCALE FEET

**Environmental Resources Management**

FIGURE 3-12
TERTIARY-BUTYL ALCOHOL IN GROUND WATER
INT UNIT (2002 vs. 2013)
French Limited Superfund Site
Crosby, Texas

| | | |
|---|---|---|
| DESIGN: S. Tomashitis | DRAWN: EFC | CHKD.: |
| DATE: 3/6/2014 | SCALE: AS SHOWN | REV.: |

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ERM

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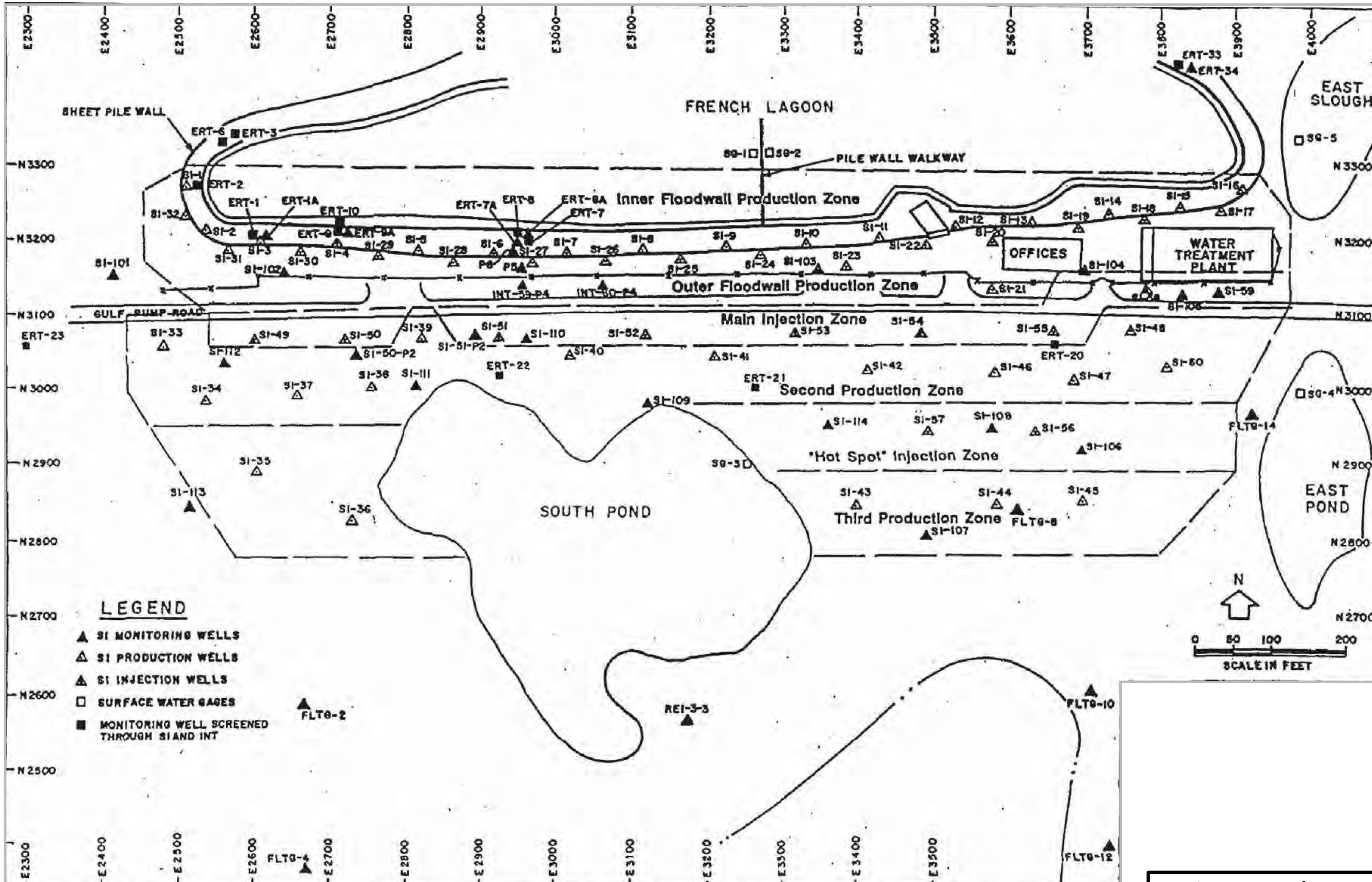


SOURCE:

FLTG, INC.
FRENCH LIMITED SITE
CROSBY, TEXAS
FIGURE 2-7
SI UNIT
PRODUCTION AND
INJECTION WELL LAYOUT
PROJECT NUMBER 26

ERM-Southwest, Inc. TX PE Firm No. 2393

**Environmental Resources Management**

FIGURE 3-13
GROUND WATER REMEDIATION SYSTEM - S1 UNIT

French Limited Superfund Site
Crosby, Texas

| | | |
|---|---|---|
| DESIGN: JLB | DRAWN: RLM | CHKD.: FMB |
| DATE: 2/26/2014 | SCALE: AS SHOWN | REV.: |

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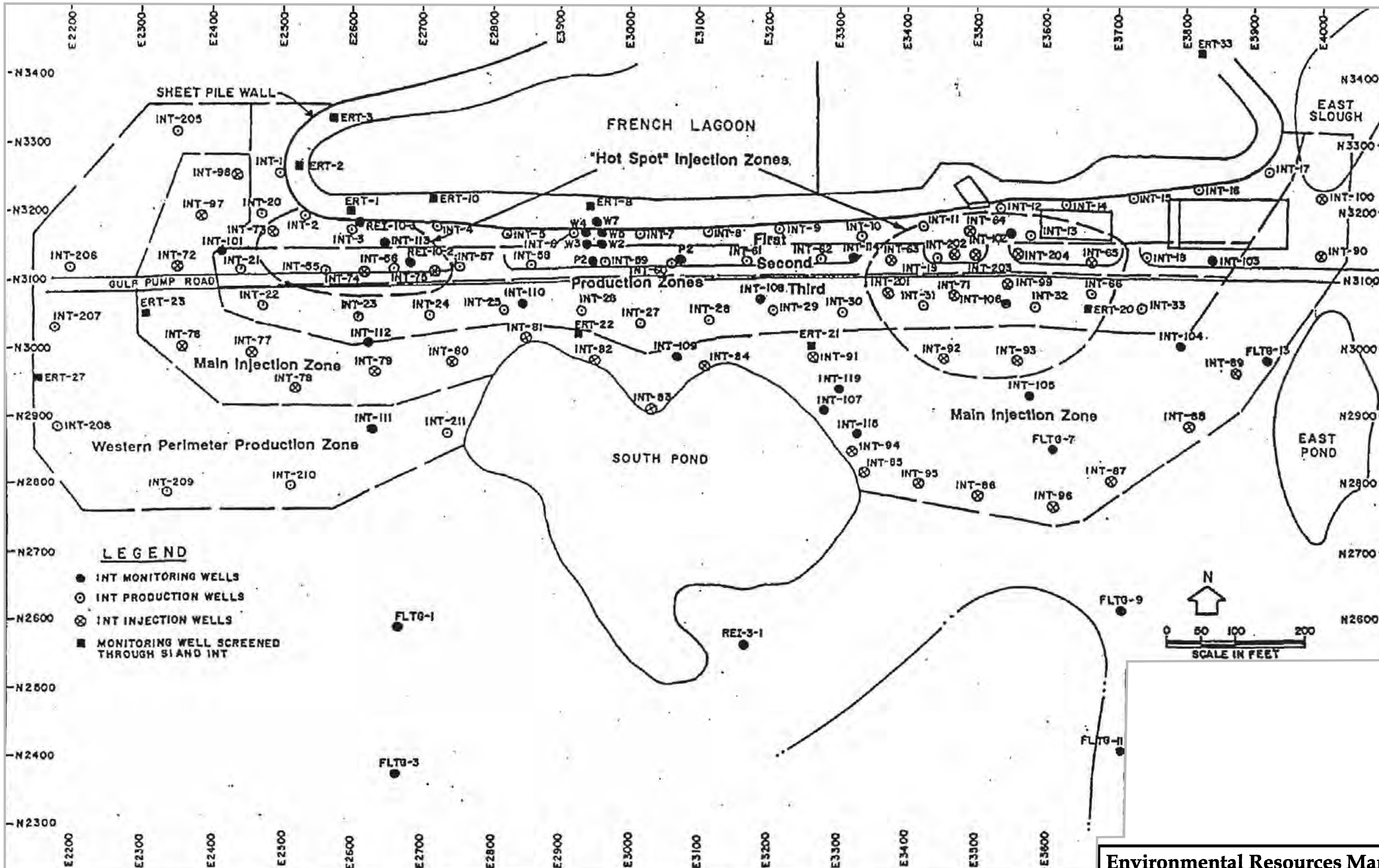



SOURCE:

FLTG, INC.
FRENCH LIMITED SITE
CROSBY, TEXAS
FIGURE 2-6
INT UNIT
PRODUCTION AND
INJECTION WELL LAYOUT
PROJECT NUMBER 26

**Environmental Resources Management**

FIGURE 3-14
GROUND WATER REMEDIATION SYSTEM - INT UNIT

French Limited Superfund Site
Crosby, Texas

| DESIGN: JLB | DRAWN: RLM | CHKD.: FMB |
|---|---|---|
| DATE: 2/26/2014 | SCALE: AS SHOWN | REV.: |

W.O.NO.: H:\DWG\B14\0234672A1.dwg, 2/26/2014 8:39:20 AM

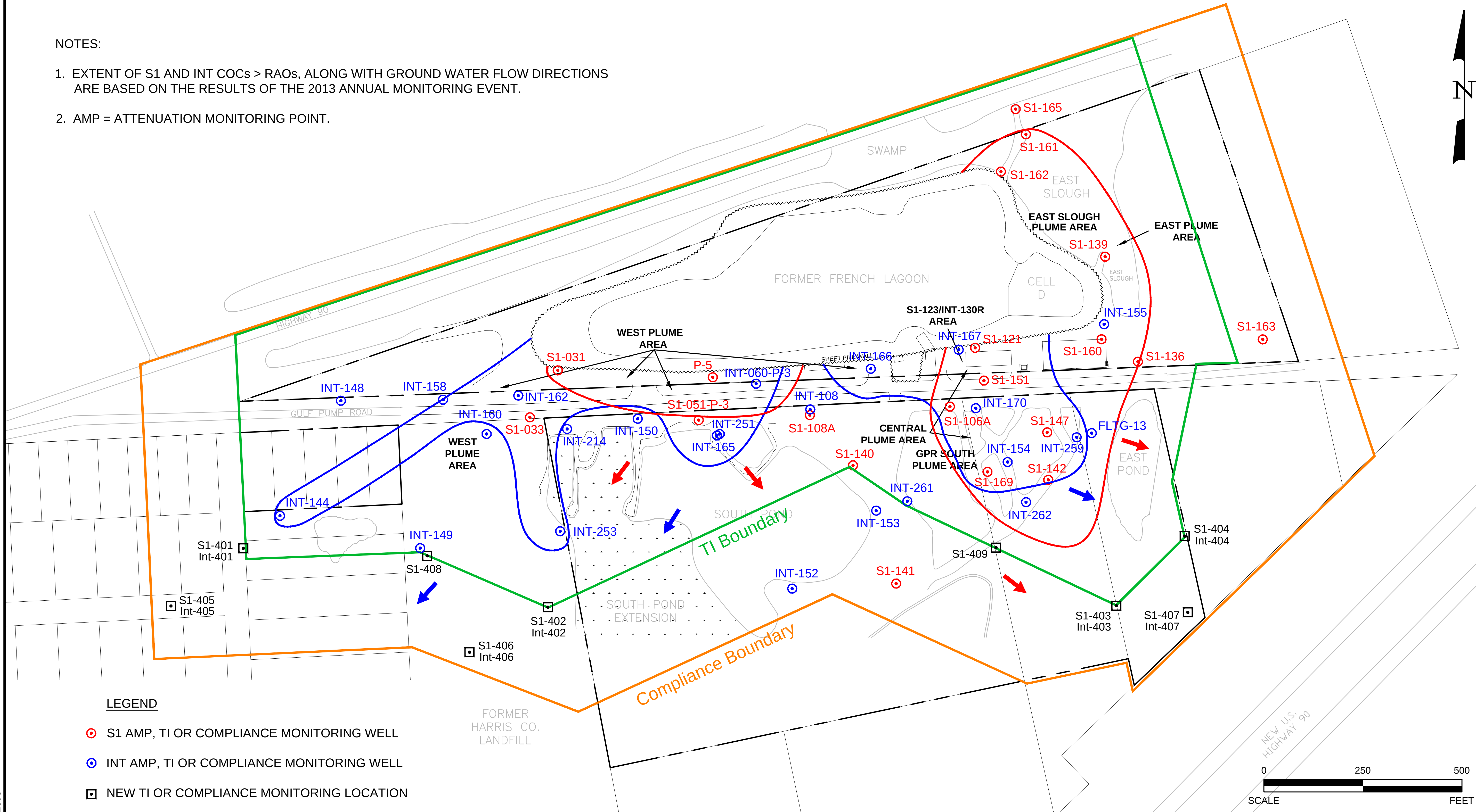
ERM

ERM-Southwest, Inc. TX PE Firm No. 2393

NOTES:

1. EXTENT OF S1 AND INT COCs > RAOs, ALONG WITH GROUND WATER FLOW DIRECTIONS ARE BASED ON THE RESULTS OF THE 2013 ANNUAL MONITORING EVENT.

2. AMP = ATTENUATION MONITORING POINT.




LEGEND

- S1 AMP, TI OR COMPLIANCE MONITORING WELL
- INT AMP, TI OR COMPLIANCE MONITORING WELL
- NEW TI OR COMPLIANCE MONITORING LOCATION
- LIMITS OF S1 COCs >RAOs
- LIMITS OF INT COCs >RAOs
- GROUND WATER FLOW DIRECTION
- SHEET PILE WALL
- SITE PROPERTY BOUNDARY

ERM-Southwest, Inc. TX PE Firm No. 2393

**Environmental Resources Management**

FIGURE 6-1
PROPOSED TI BOUNDARY AND MONITORING LOCATIONS
French Limited Superfund Site
Crosby, Texas

ERM

| DESIGN: R. Jaros | DRAWN: EFC | CHKD.: FMB |
|---|---|---|
| DATE: 3/27/2014 | SCALE: AS SHOWN | REV.: |

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# High-Resolution Site Characterization Study

*Appendix A*

*April 2, 2014*
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000

## High Resolution Source Characterization Program

Environmental Resources Management (ERM) conducted a phased high-resolution site characterization (HRSC) program to further refine the conceptual site model (CSM) in an area of interest in the Central Plume Area portion of the French Limited Superfund Site (the Site) located in Crosby, Texas. The area of interest is located adjacent to the sheet pile wall along Gulf Pump Road. A Locus Map showing the area of interest (also referred to as the study area) is included as Figure A-1.

In Phase One of the HRSC program, conducted during December 2011 and January 2012, data were collected using a cone penetrometer testing (CPT) unit and a membrane interface probe (MIP). The data were supplemented during Phase Two of the HRSC program, conducted in March 2013, with data collected using the Waterloo Advanced Profiling System (Waterloo$^{APS}$).

### *CPT/MIP*

The Phase One CPT/MIP program investigated 26 of the 40 staked locations within the Central Plume Area to locate areas of residual constituent of concern (COC) mass in the subsurface. The locations were roughly 80 feet apart in an east-west direction and roughly 70 feet apart in a north-south direction. Consistent with ERM Subsurface Clearance protocols, each location was cleared by geophysical survey prior to surface penetration and local utilities were notified (One-Call) to mark existing easements and lines.

Fugro Consultants, Inc. provided the 25 ton direct-push rig, which advanced the CPT/MIP tool through the subsurface. CPT is a method for characterizing subsurface soil conditions by measuring the tip resistance and sleeve friction as drill tools are advanced through the subsurface. The CPT tooling is advanced through the soil at a relatively constant rate by application of a hydraulic press mounted in a large, heavy truck or all-terrain vehicle (ATV). The tip resistance and sleeve friction measurements, along with the ratio of these two parameters have been correlated to a wide range of soil types. Accordingly, CPT vendors have developed software that converts the CPT measurements to known soil types, resulting in real-time development of continuous digital logs of recorded measurements and soil types with depth.

The MIP was advanced at a rate of approximately one foot per minute (ft/min). When necessary, borehole advancement was halted every foot to allow the heater plate to achieve the optimal temperature range (i.e., 100 to 120 °C). The probe on the MIP is equipped with a porous polytetrafluoroethene membrane set into a steel plate that is electrically heated to the optimal temperature range. The heat volatilizes organic compounds present in the soil and/or groundwater adjacent to the tip. Volatile organic compounds (VOCs), up to a maximum molecular size (i.e., molecules up to the size of naphthalene), pass through the membrane by diffusion under a concentration gradient. Once a compound has passed through the membrane, it is picked up by a carrier gas (i.e., nitrogen) running through a tubing loop (i.e., trunk line). The organic compounds are carried to the surface where they pass through serial detectors that include:

- a photoionization detector (PID) to measure aromatic compounds;

- an electron capture detector (ECD) to measure CVOCs; and
- a flame ionization detector (FID) to measure straight chain hydrocarbons (e.g., methane) and elevated concentrations of some chlorinated compounds.

Results are reported continuously as detector response in microvolts (uV) versus depth and represent relative total VOC concentrations. The ECD is a very sensitive detector and is capable of detecting chlorinated volatile organic compounds (CVOCs) at low concentrations (i.e., down to about 200 micrograms per liter for trichloroethene (TCE)); however, the detector saturates at high concentrations (above approximately 20,000 ug/L for TCE). The PID and FID can also detect CVOCs if they are present at high enough concentrations. Since the concentration ranges for detection of CVOCs by ECD, PID and FID overlap, the results from the detectors can be combined to evaluate a broad range of CVOC concentrations in soil gas, soil and groundwater.

The CPT and MIP logs are included in Appendix B and C of this report, respectively

***WATERLOO ADVANCED PROFILING SYSTEM (WATERLOO$^{APS}$)***

The Phase Two work plan was designed to collect quantitative contaminant speciation and concentration data from zones of elevated COC mass identified by the MIP. The Phase II Waterloo Advanced Profiling System (Waterloo$^{APS}$) program investigated 12 of the 26 CPT/MIP locations to provide quantitative contaminant speciation and concentration data. The Waterloo$^{APS}$ data was also used to further characterize the hydrogeologic system.

The surface locations chosen for the French Limited site were based off of previous CPT/MIP locations, and were generally placed within a few feet of those locations. The locations were then hydro-excavated down to five feet to visually ensure no underground utilities were to be encountered.

Stone Environmental provided the Waterloo$^{APS}$, which is a proprietary direct-push groundwater sampling tool, which generates a continuous log of the index of hydraulic conductivity (Ik). The Ik is determined by measuring the flow rate and pressure of water injected into the formation as the tool is driven. The vertically continuous Ik data provide high-resolution information on hydrostratigraphic changes in real-time.

The Waterloo$^{APS}$ collected groundwater samples from multiple intervals as the tool was advanced without having to withdraw the tool for sample collection or decontamination. During advancement of the tool through relatively homogeneous geologic material exhibiting adequate hydraulic conductivity values, groundwater samples were collected at approximately 5-ft intervals. When the geologic conditions were heterogeneous, groundwater samples were collected at interfaces between relatively high and relatively low permeability units (i.e., the samples were collected from the higher permeability zone). The Waterloo$^{APS}$ was not able to collect groundwater samples from zones of low permeability.

The Waterloo$^{APS}$ was used to collect depth-discrete hydraulic head data and groundwater samples from a 5-inch vertical interval. At each sampling depth groundwater was purged until equilibrium of field parameters (i.e., pH, temperature, dissolved oxygen, oxygen reduction potential, and specific conductance) and groundwater samples were collected for laboratory analysis. A total of 44 discrete-interval groundwater samples were collected and submitted to ALS Environmental of Houston, Texas for laboratory analysis of VOCs by EPA Method 8260.

The Waterloo$^{APS}$ logs are included in Appendix D of this report.

*INTERPRETATION OF THE COLLABORATIVE DATASET*

All of the high resolution characterization tools used in the Central Plume Area have inherent strengths and weaknesses. The tools used at this Site complement each other in that their relative strengths offset each other's relative weaknesses. For example:

- The CPT measures physical properties whereas the Waterloo$^{APS}$ measures hydrologic properties of soil. In general, data collected using these two methods produced similar interpretations of hydrogeologic conditions. However, in cases where data from the two tools differed, ERM relied on groundwater sample equilibration rates measured using the Waterloo$^{APS}$ to determine if a geologic interval exhibits relatively high or low permeability.
- When the MIP is advanced through an interval containing significant contaminant mass, there can be a carry-over effect that can exaggerate the apparent vertical extent of contamination (Bumberger et al., 2012). In general, discrete-interval groundwater sampling data collected with the Waterloo$^{APS}$ were compared with MIP data to define the vertical extent of contamination.
- The MIP uses three detectors, which have different sensitivities to different compounds. As such, the MIP detector responses can vary depending on the mixture of compounds present. Discrete-interval groundwater sampling data collected with the Waterloo$^{APS}$ were used in conjunction with MIP data to define zones containing elevated COC mass.

As such, to develop a rigorous CSM, it was necessary to interpret the collaborative dataset rather than relying on data from any one tool.


ERM-Southwest, Inc. TX PE Firm No. 2393

# Cone Penetrometer Testing (CPT) Logs

*Appendix B*

*April 2, 2014*
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000

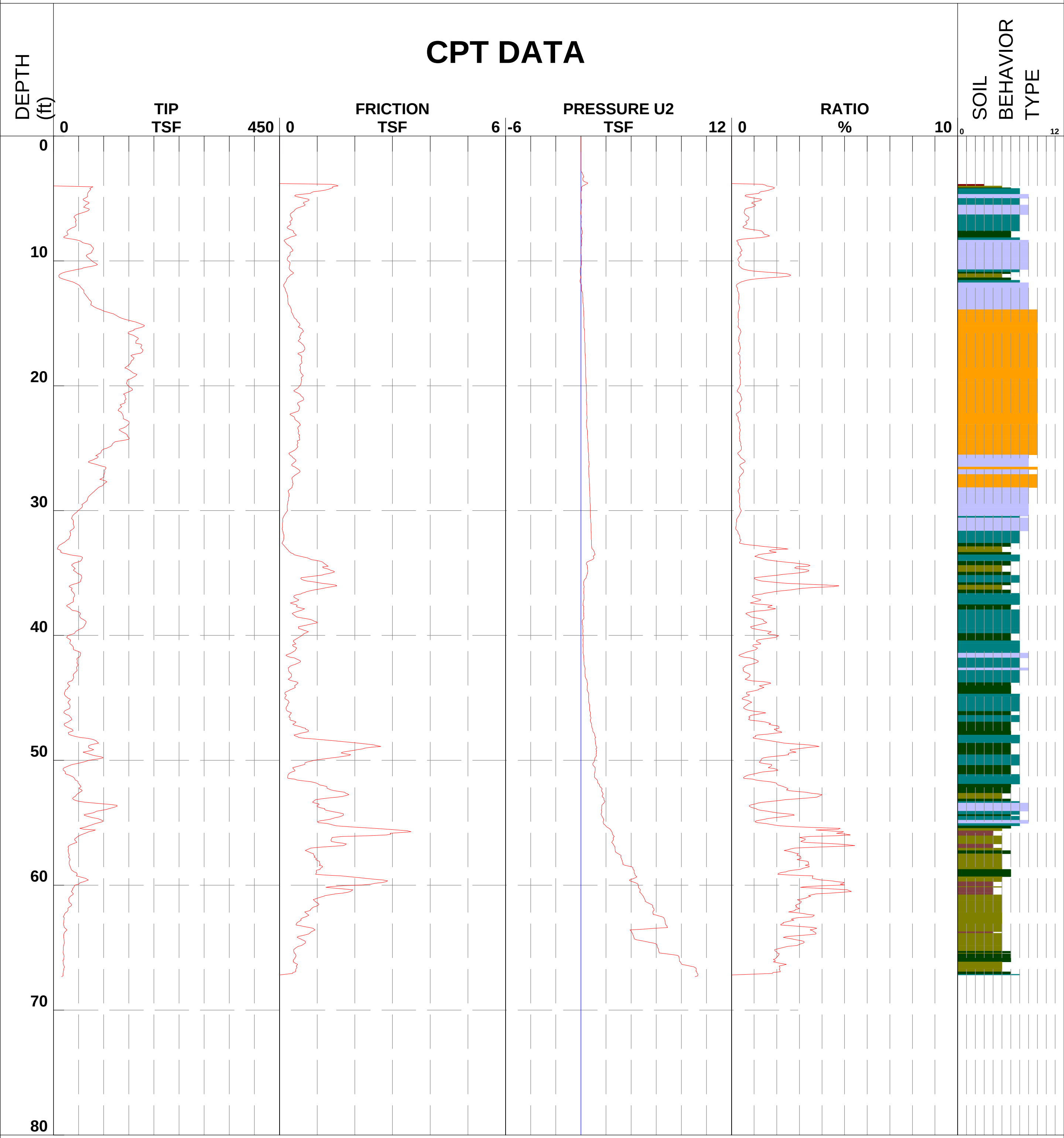
# CPT Data

Job Number 04.1911-0063 | CPT Number MIP-A-01 | LocatiFormer French Ltd. Site Crosby, TX

Operator Albert Fonseca | Date and Tin 20-Dec-2011 13:07:18 | Cone Number A15F2.5CKE2H2112

Client ERM

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

Robertson et al. 1986 * Overconsolidated or Cemented

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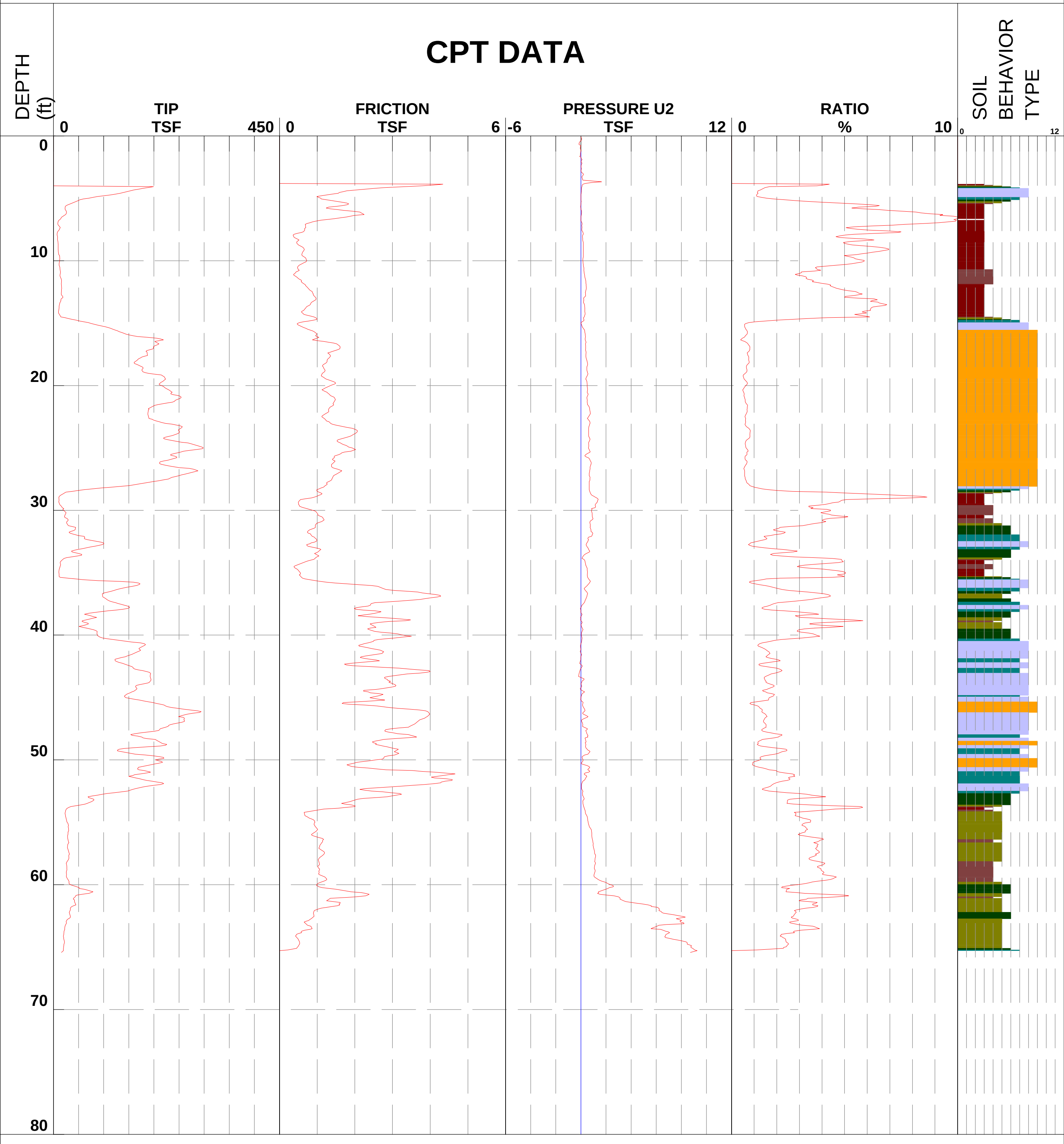
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-A-02A
LocatiFormer French Ltd. Site Crosby, TX
Operator Herbert Jackson
Date and Tim 10-Jan-2012 11:30:14
Cone Number F7.5CKE2HAW21935
Client ERM

***4' augered***



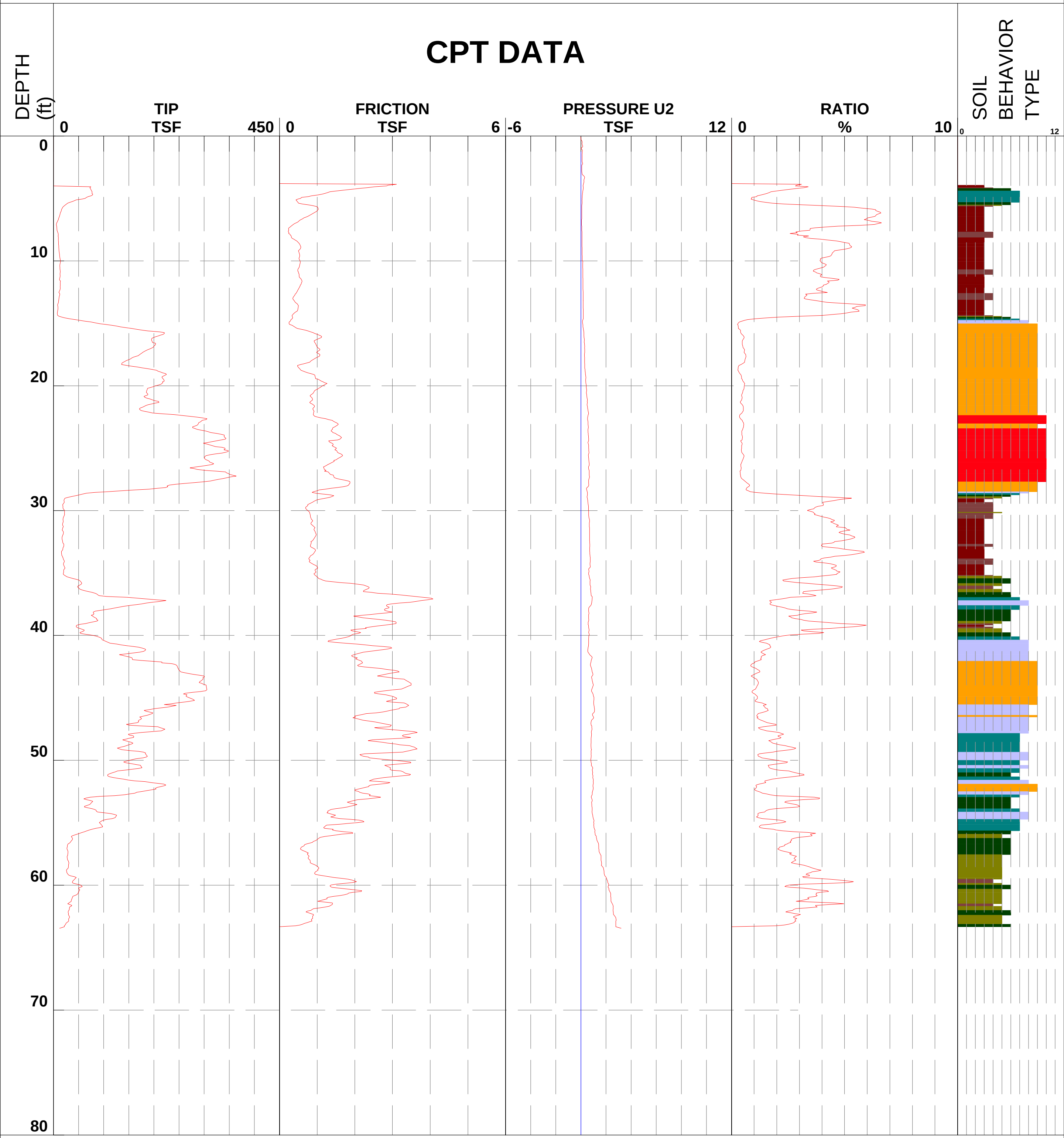

1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

Robertson and Campanella 1986 * Overconsolidated or Cemented

# CPT Data

Job Number 04.1911-0063
CPT Number MIP-A-03
LocatiFormer French Ltd. Site Crosby, TX
Operator Albert Fonseca
Date and Tin 19-Dec-2011 15:22:10
Cone Number A15F2.5CKE2H2112
Client ERM

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

Robertson et al. 1986 * Overconsolidated or Cemented

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# CPT Data

Job Number 04.1911-0063

CPT Number MIP-A-04

LocatiFormer French Ltd. Site Crosby, TX

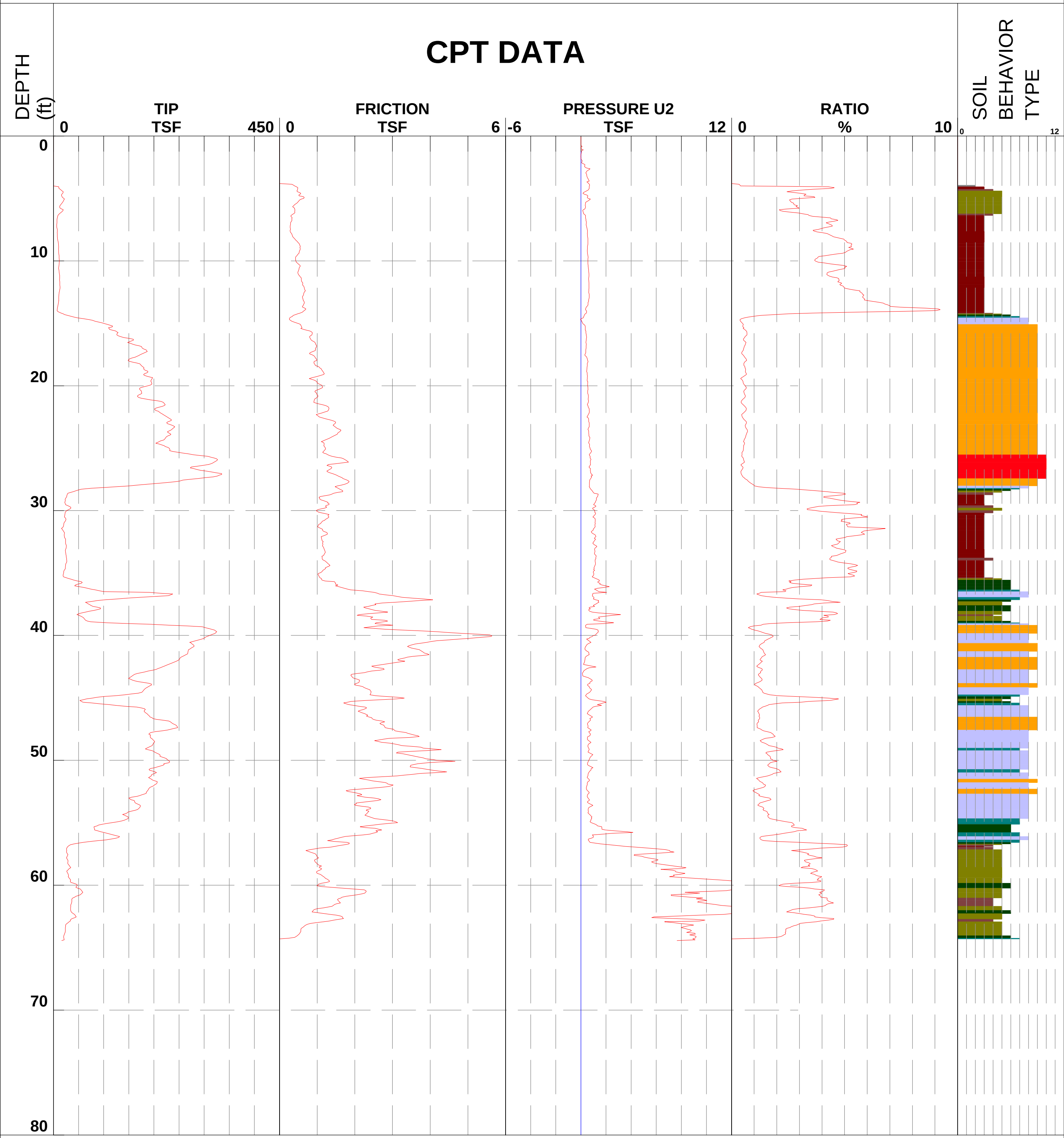
Operator Herbert Jackson

Date and Tir 10-Jan-2012 13:42:42

Cone Number F7.5CKE2HAW21935

Client ERM

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

Robertson4et al. 1986 * Overconsolidated or Cemented

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# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-A-05 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Albert Fonseca | Date and Tin | 19-Dec-2011 13:22:43 | Cone Number | A15F2.5CKE2H2112 |
| Client | ERM | | | | |

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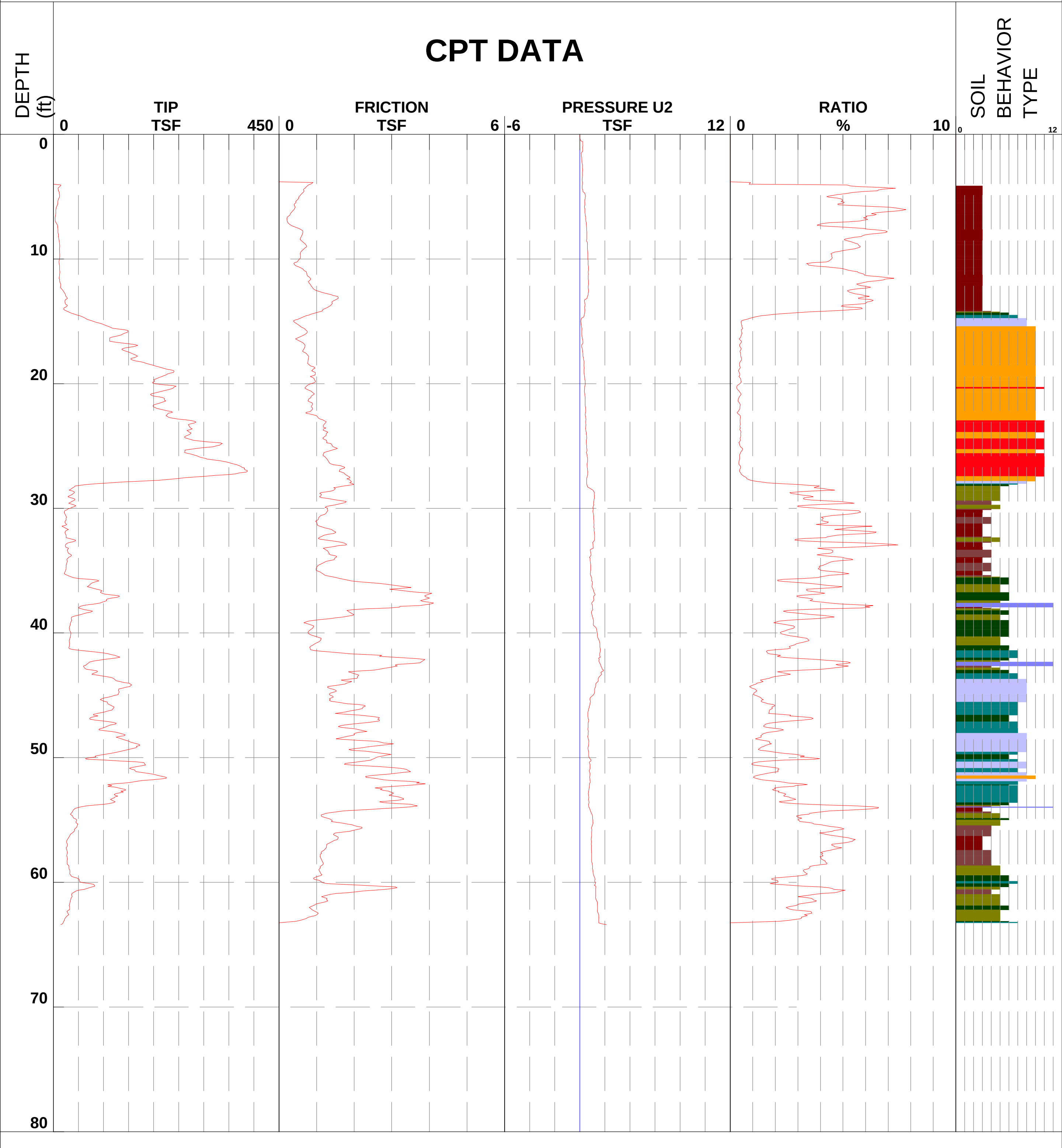


| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

Robertson et al. 1986 * Overconsolidated or Cemented

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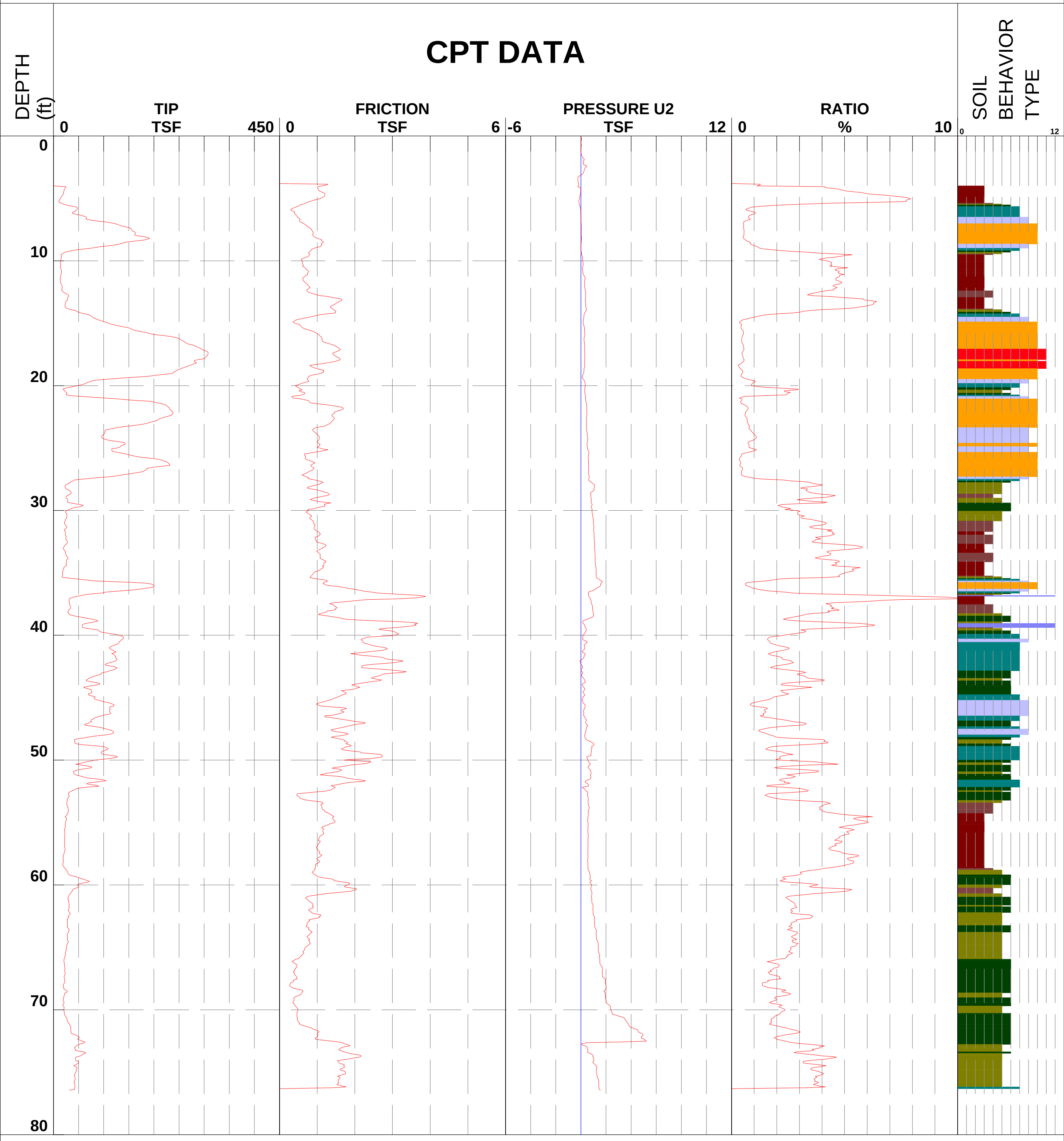
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-A-06
LocatiFormer French Ltd. Site Crosby, TX
Operator Jared Louviere
Date and Tim 05-Jan-2012 09:38:02
Cone Number A15F2.5CKE2H2112
Client ERM

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

Robertson et al. 1986 * Overconsolidated or Cemented

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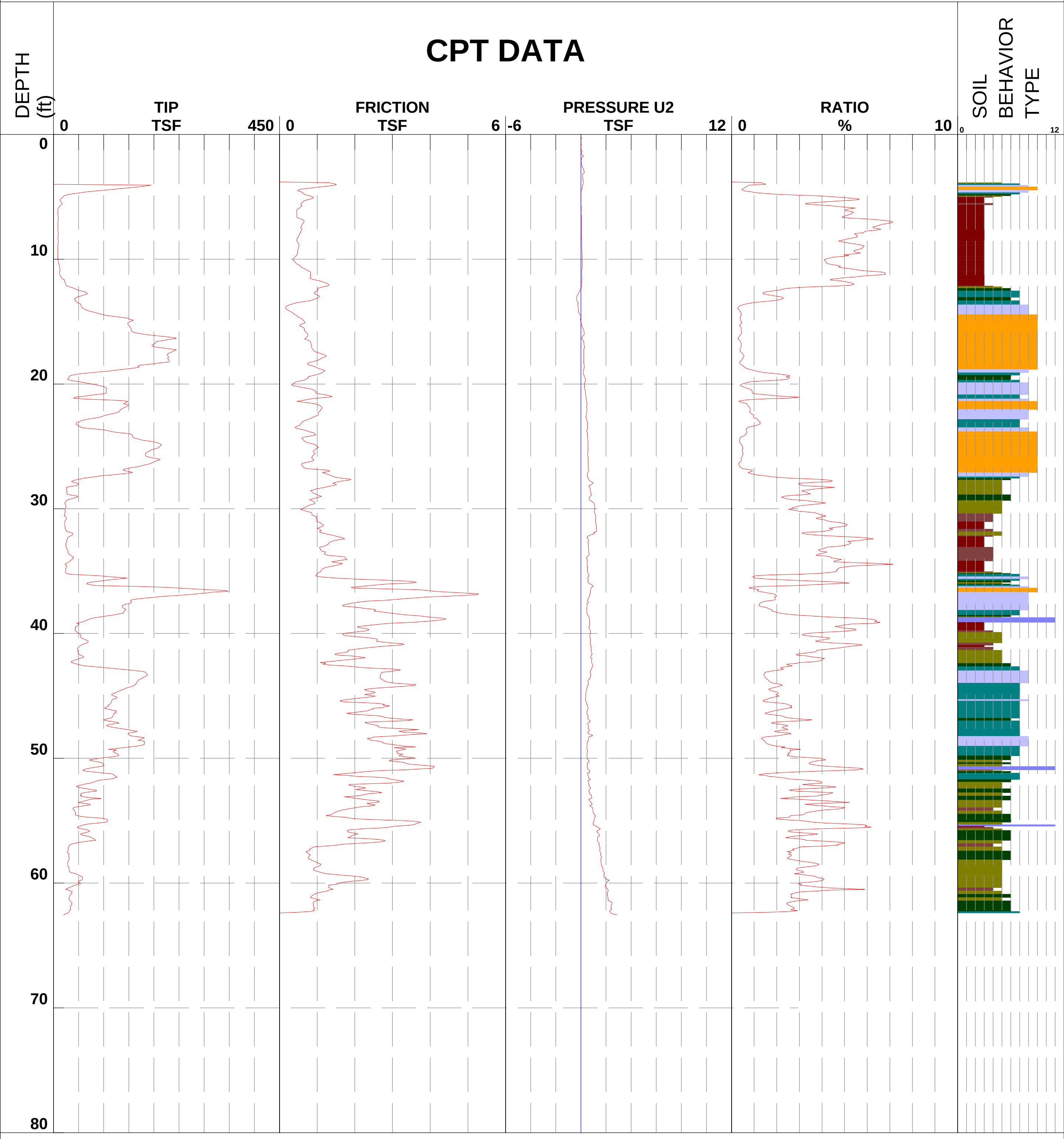
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-A-07 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Albert Fonseca | Date and Tin | 19-Dec-2011 10:21:36 | Cone Number | A15F2.5CKE2H2112 |
| Client | | ERM | | | |

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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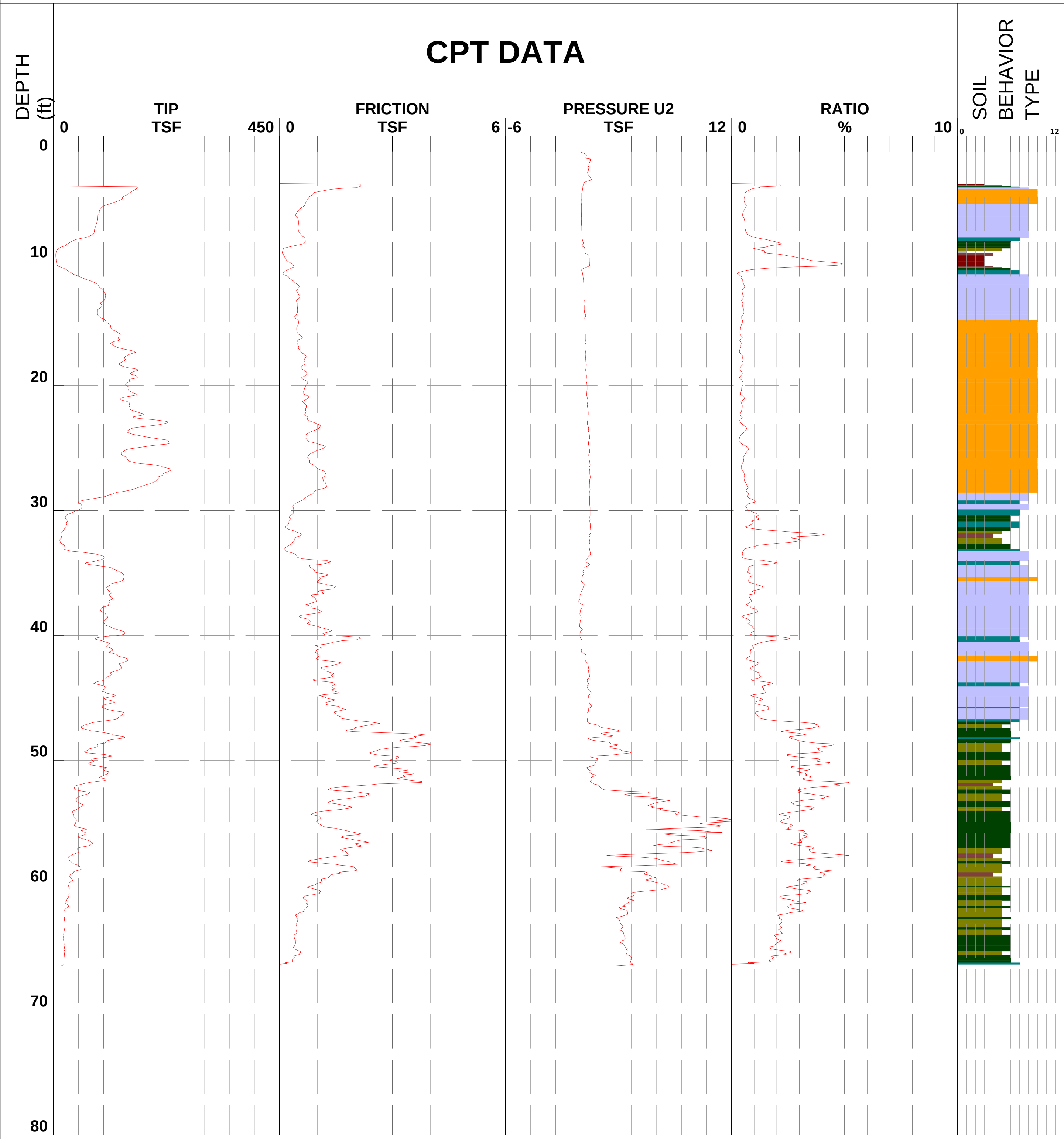
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-B-01 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Jared Louviere | Date and Tir | 06-Jan-2012 09:22:04 | Cone Number | A15F2.5CKE2H2112 |
| Client | ERM | | | | |

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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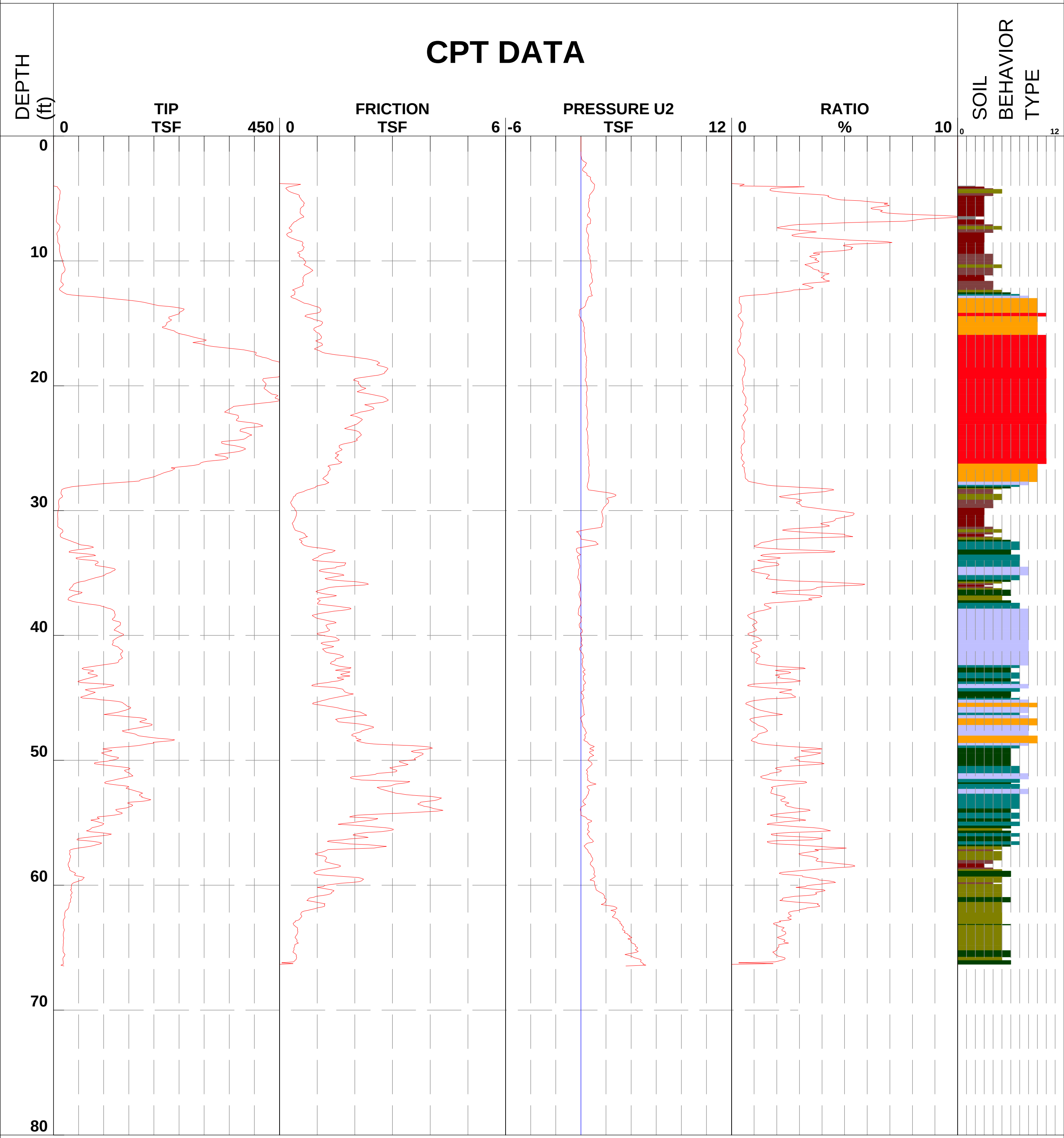
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-B-02 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Jared Louviere | Date and Tin | 06-Jan-2012 12:11:36 | Cone Number | A15F2.5CKE2H2112 |
| Client | ERM | | | | |

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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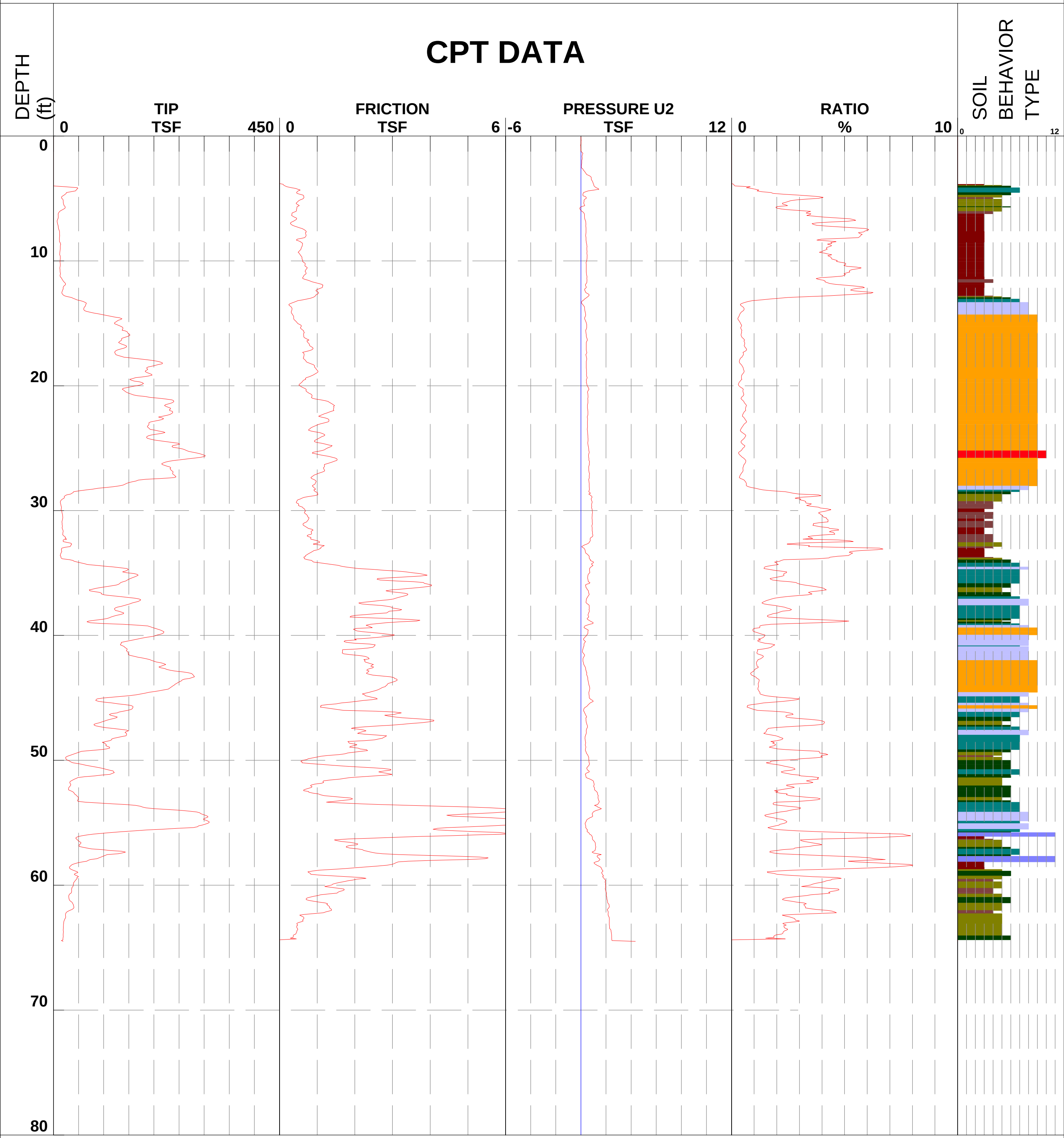
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-B-03
LocatiFormer French Ltd. Site Crosby, TX
Operator Jared Louviere
Date and Tin 06-Jan-2012 14:15:07
Cone Number A15F2.5CKE2H2112
Client ERM

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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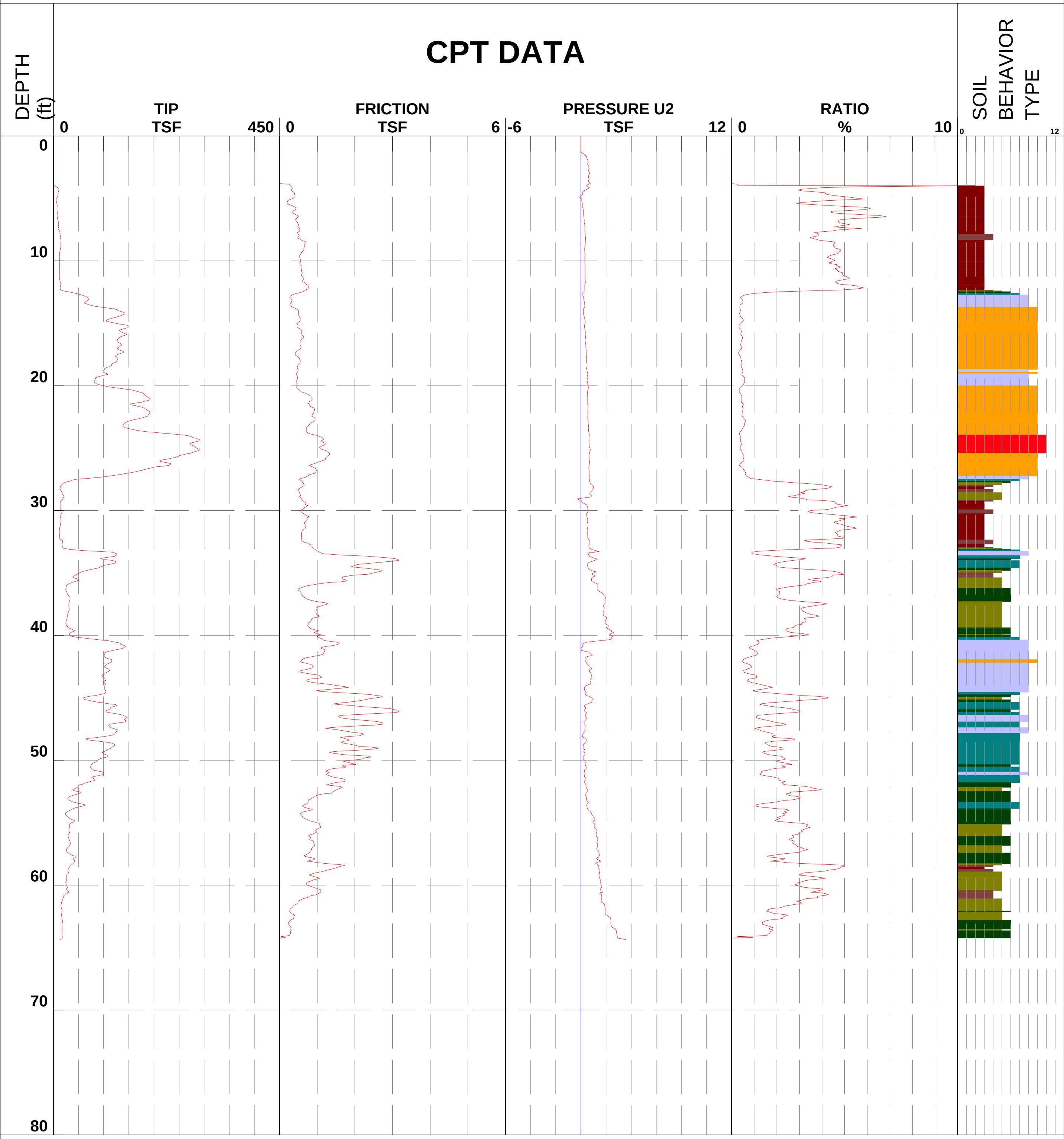
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-B-04 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Jared Loviere | Date and Tim | 04-Jan-2012 07:51:02 | Cone Number | A15F2.5CKE2H2112 |
| Client | ERM | | | | |

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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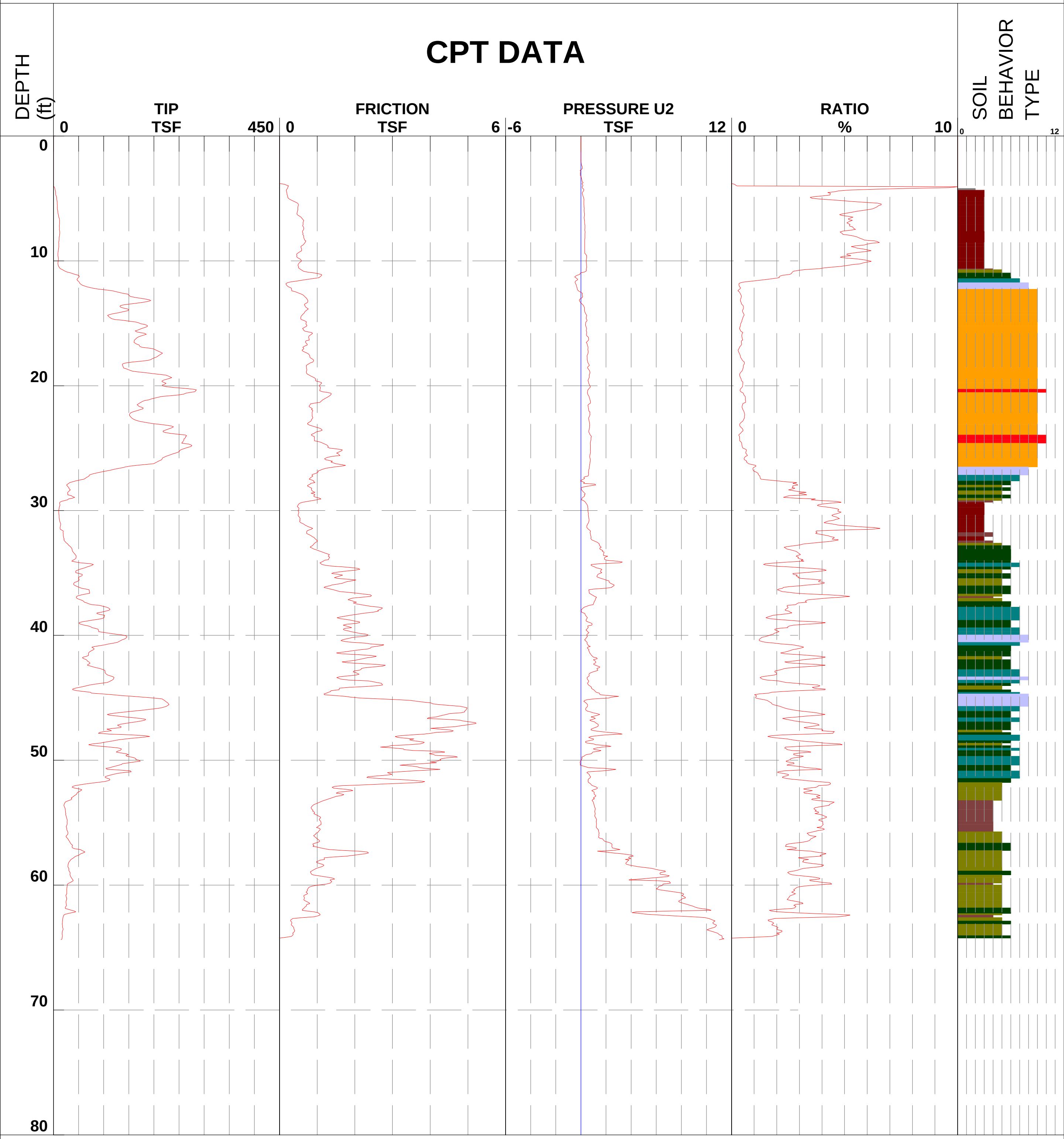
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-B-05 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Jared Loviere | Date and Tim | 03-Jan-2012 14:44:22 | Cone Number | A15F2.5CKE2H2112 |
| Client | | | ERM | | |

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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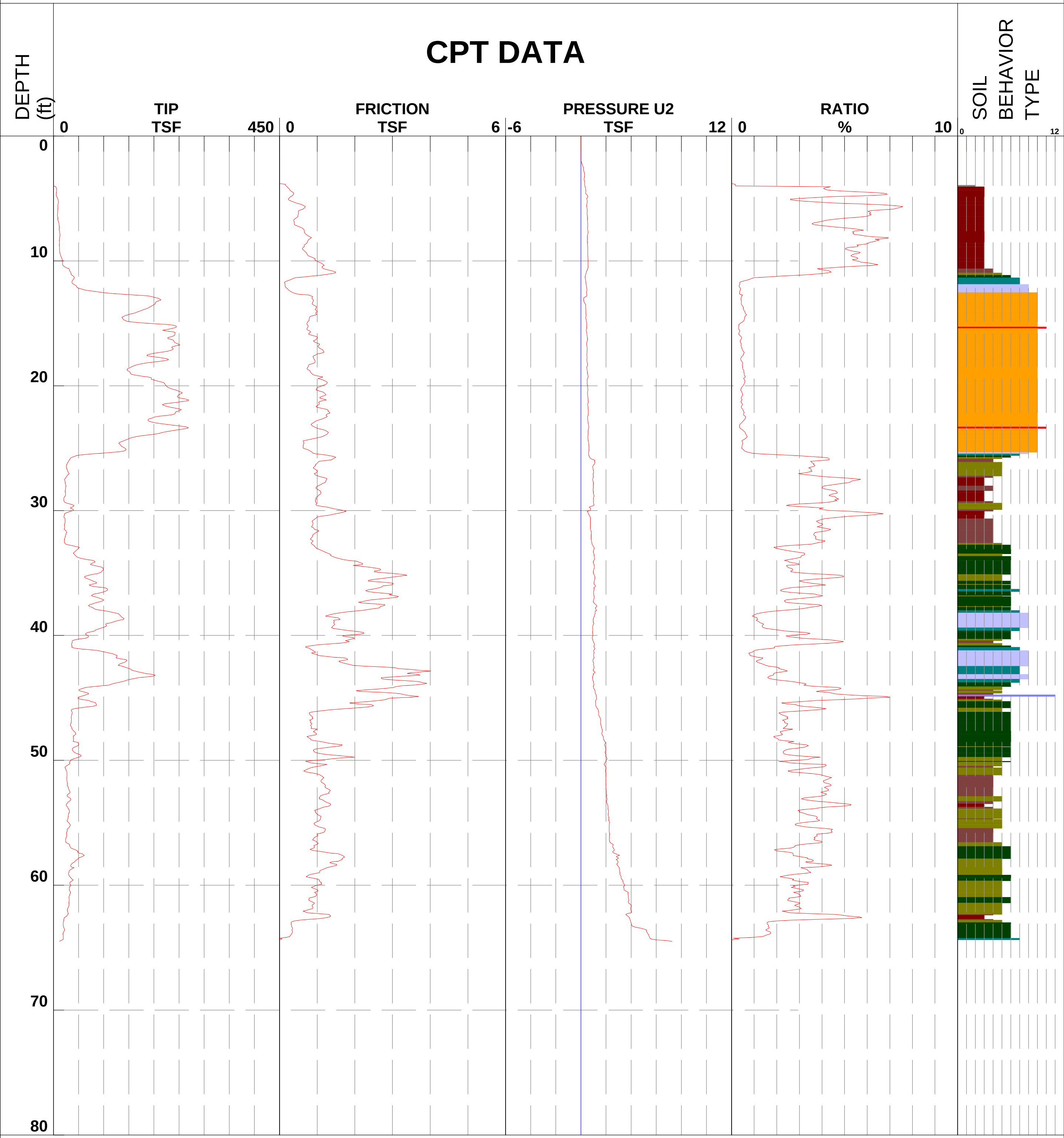
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-B-06 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Jared Loviere | Date and Tim | 03-Jan-2012 12:00:48 | Cone Number | A15F2.5CKE2H2112 |
| Client | | ERM | | | |

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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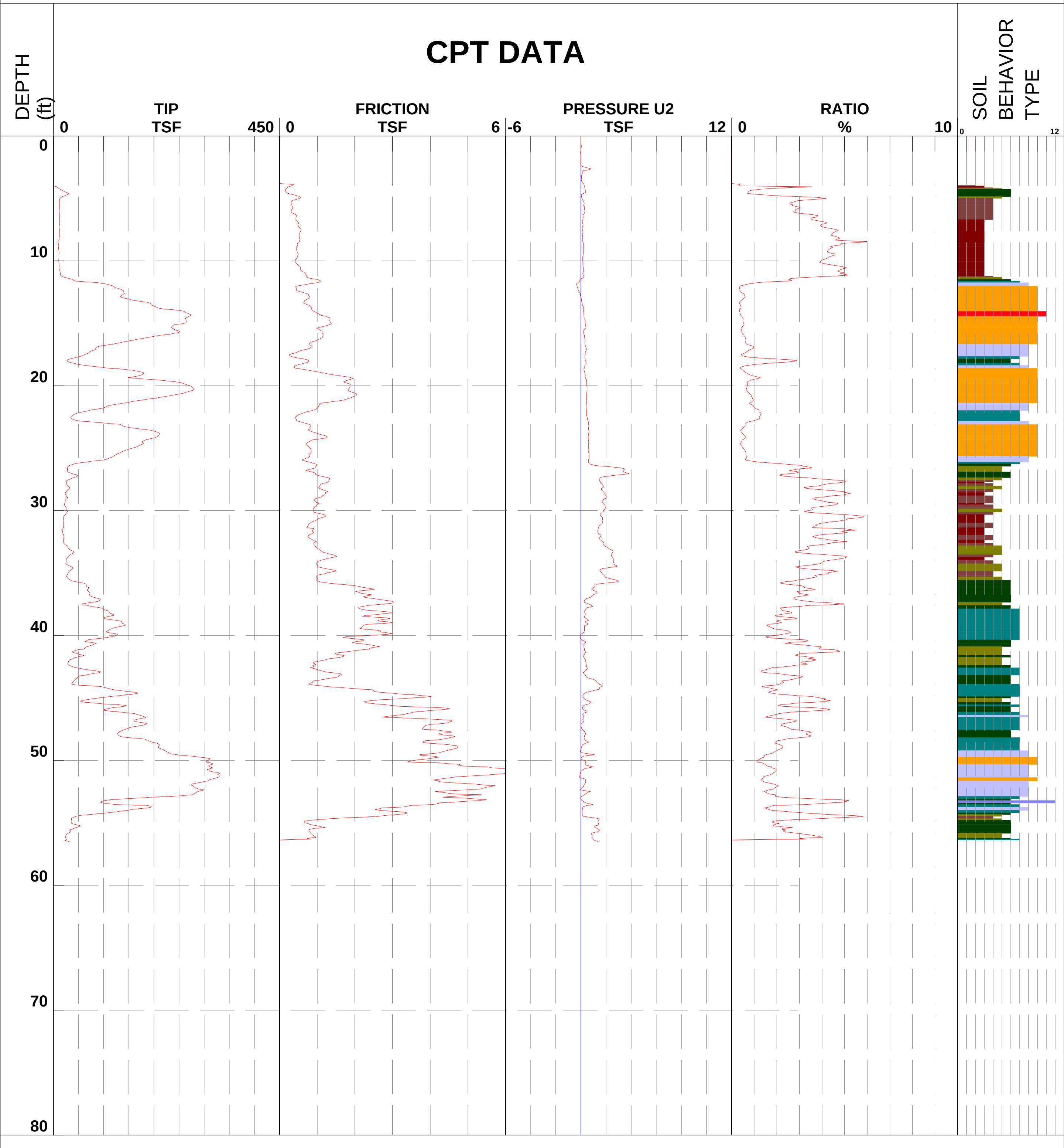
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-B-07 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Jared Louviere | Date and Tim | 04-Jan-2012 10:30:45 | Cone Number | A15F2.5CKE2H2112 |
| Client | | | ERM | | |

***4' augered***

## CPT DATA




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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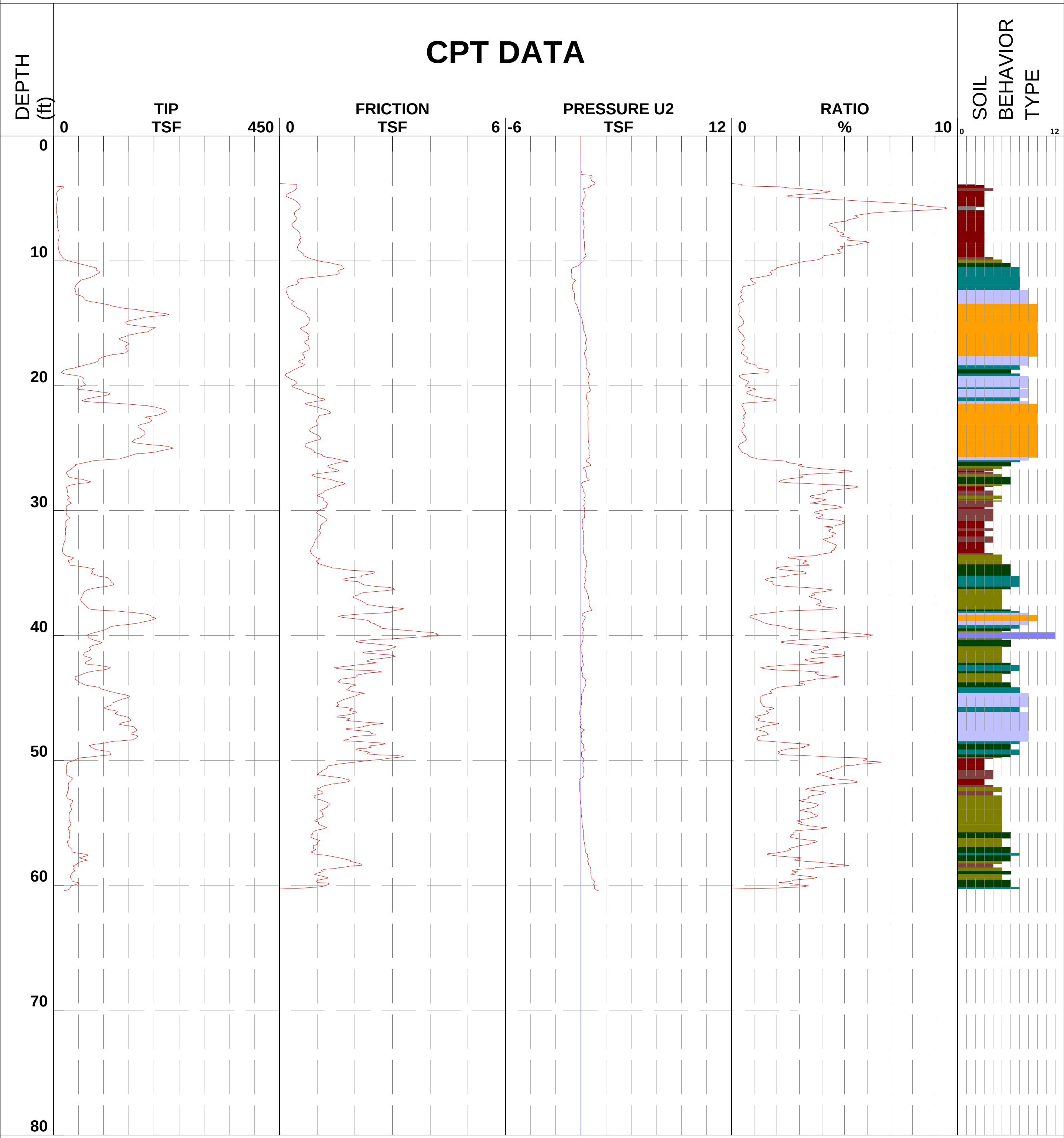
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-B-08
LocatiFormer French Ltd. Site Crosby, TX
Operator Jared Louviere
Date and Tim 05-Jan-2012 13:09:46
Cone Number A15F2.5CKE2H2112
Client ERM

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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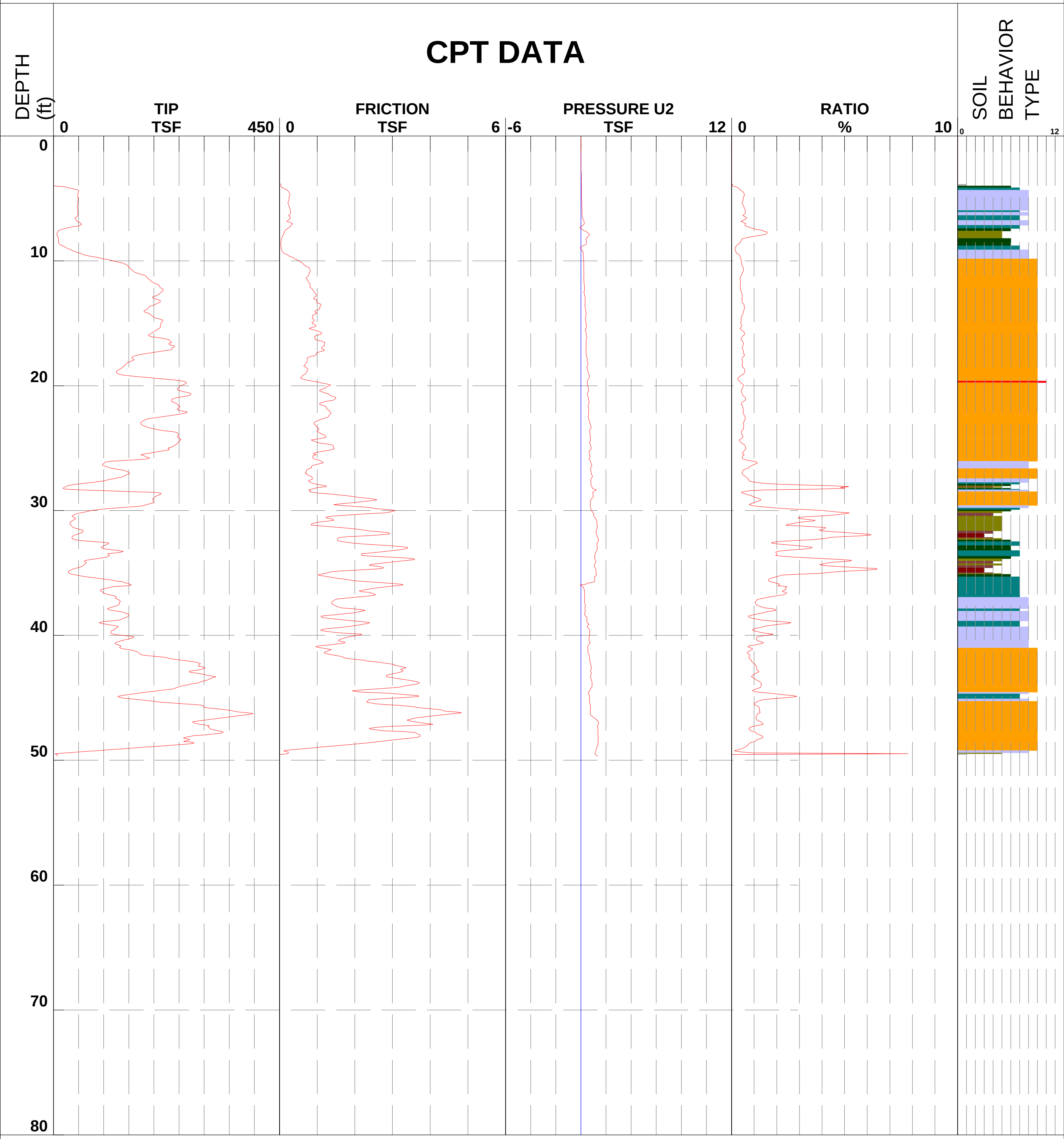
# CPT Data

Job Number 04.1911-0063 | CPT Number MIP-C-01 | LocatiFormer French Ltd. Site Crosby, TX

Operator Jared Loviere | Date and Tin 21-Dec-2011 07:42:57 | Cone Number A15F2.5CKE2H2112

Client ERM

***4' augered***




1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand

2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*)

3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*)

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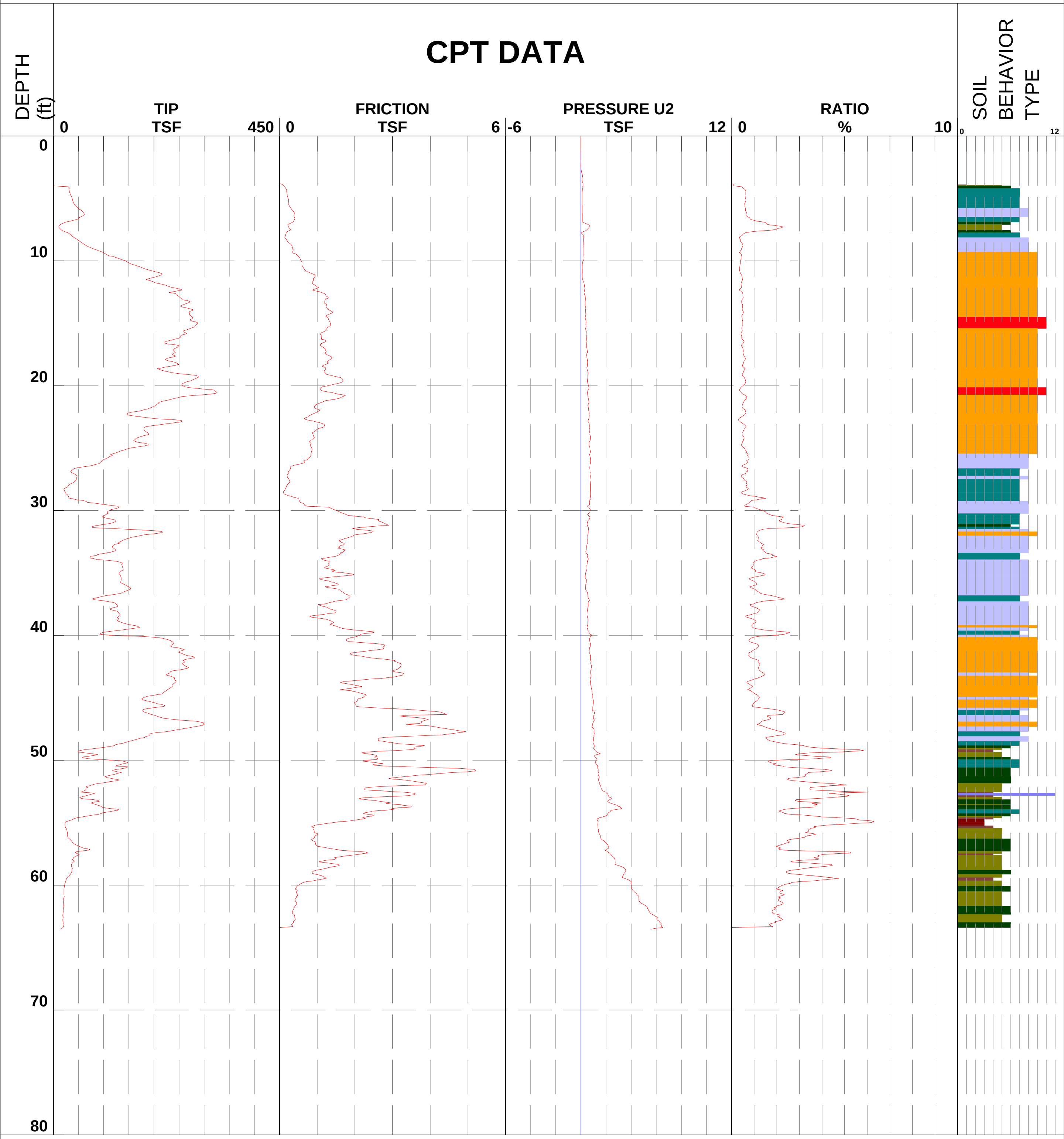
# CPT Data

| | | | | | |
|---|---|---|---|---|---|
| Job Number | 04.1911-0063 | CPT Number | MIP-C-03 | LocatiFormer | French Ltd. Site Crosby, TX |
| Operator | Jared Loviere | Date and Tin | 21-Dec-2011 10:40:03 | Cone Number | A15F2.5CKE2H2112 |
| Client | ERM | | | | |

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

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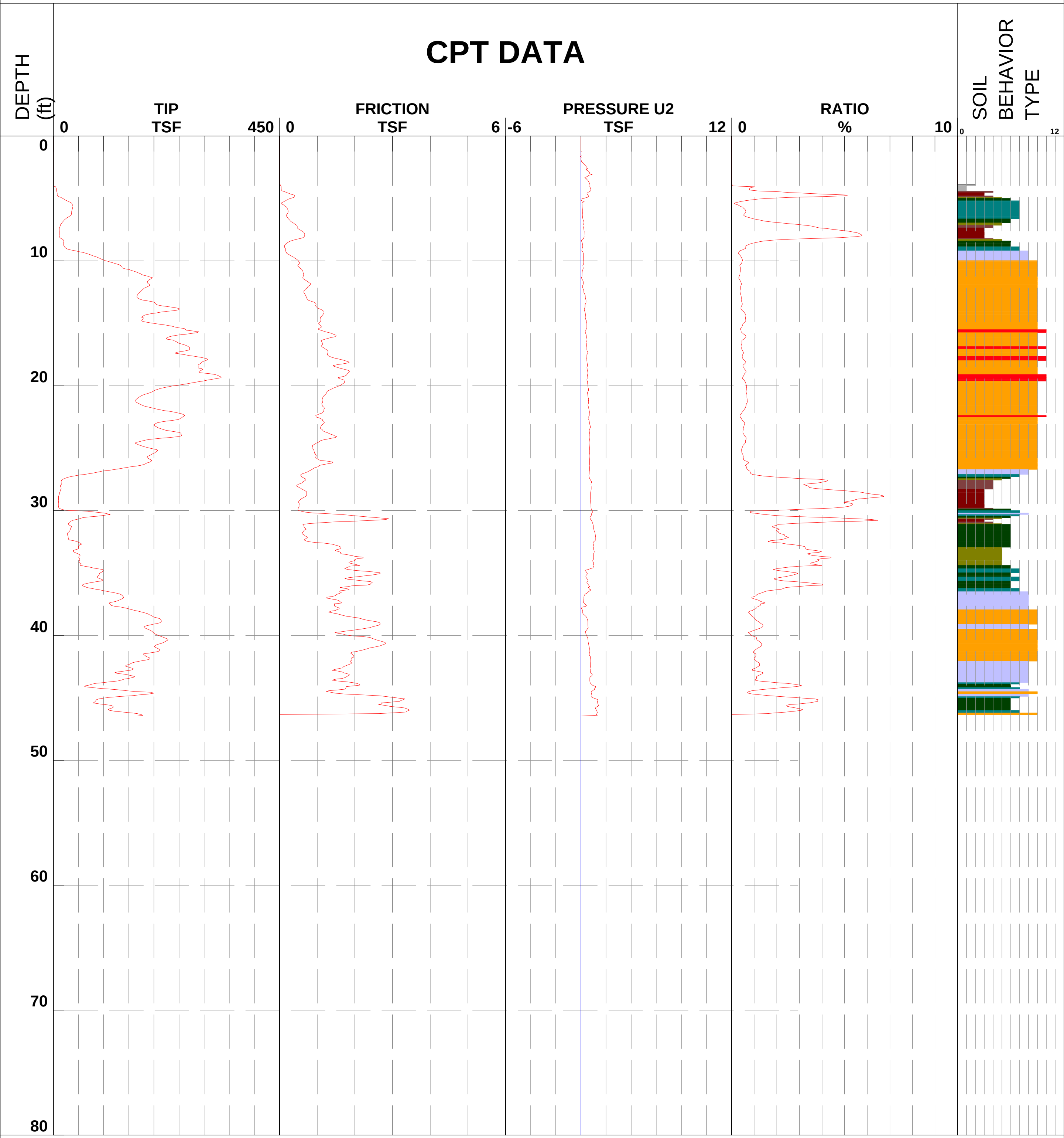
# CPT Data

Job Number 04-1911-0063
CPT Number MIP-C-04
LocatiFormer French Ltd. Site Crosby, TX
Operator Jared Louviere
Date and Tir 05-Jan-2012 07:54:52
Cone Number A15F2.5CKE2H2112
Client ERM

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

Robertson et al. 1986 * Overconsolidated or Cemented



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# CPT Data

Job Number 04.1911-0063

CPT Number MIP-C-05

LocatiFormer French Ltd. Site Crosby, TX

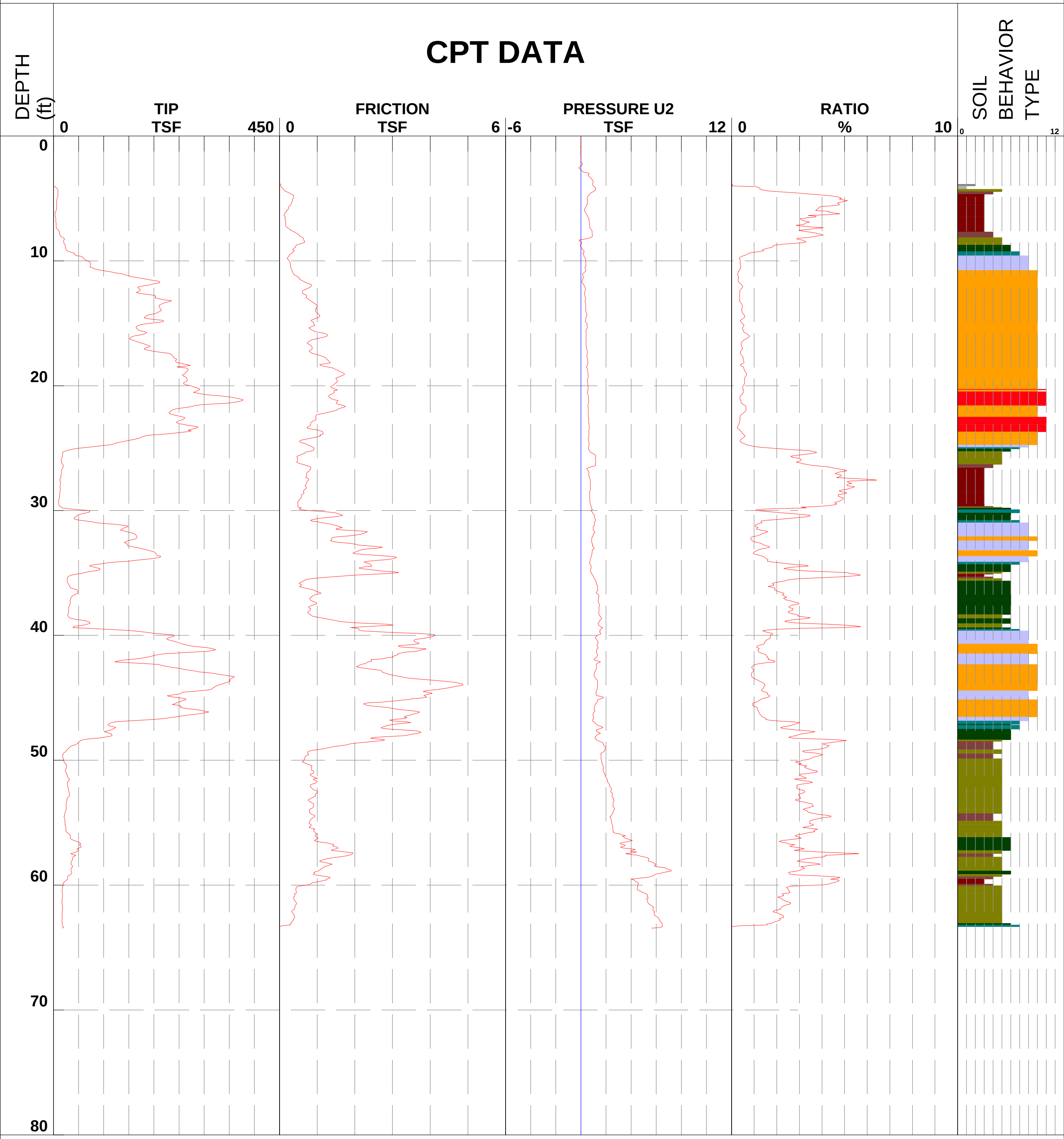
Operator Jared Loviere

Date and Tin 21-Dec-2011 13:05:45

Cone Number A15F2.5CKE2H2112

Client ERM

***4' augered***




1 - sensitive fine grained

2 - organic material

3 - clay

4 - silty clay to clay

5 - clayey silt to silty clay

6 - sandy silt to clayey silt

7 - silty sand to sandy silt

8 - sand to silty sand

9 - sand

10 - gravelly sand to sand

11 - very stiff fine grained (*)

12 - sand to clayey sand (*)

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# CPT Data

Job Number 04.1911-0063

CPT Number MIP-C-06

LocatiFormer French Ltd. Site Crosby, TX

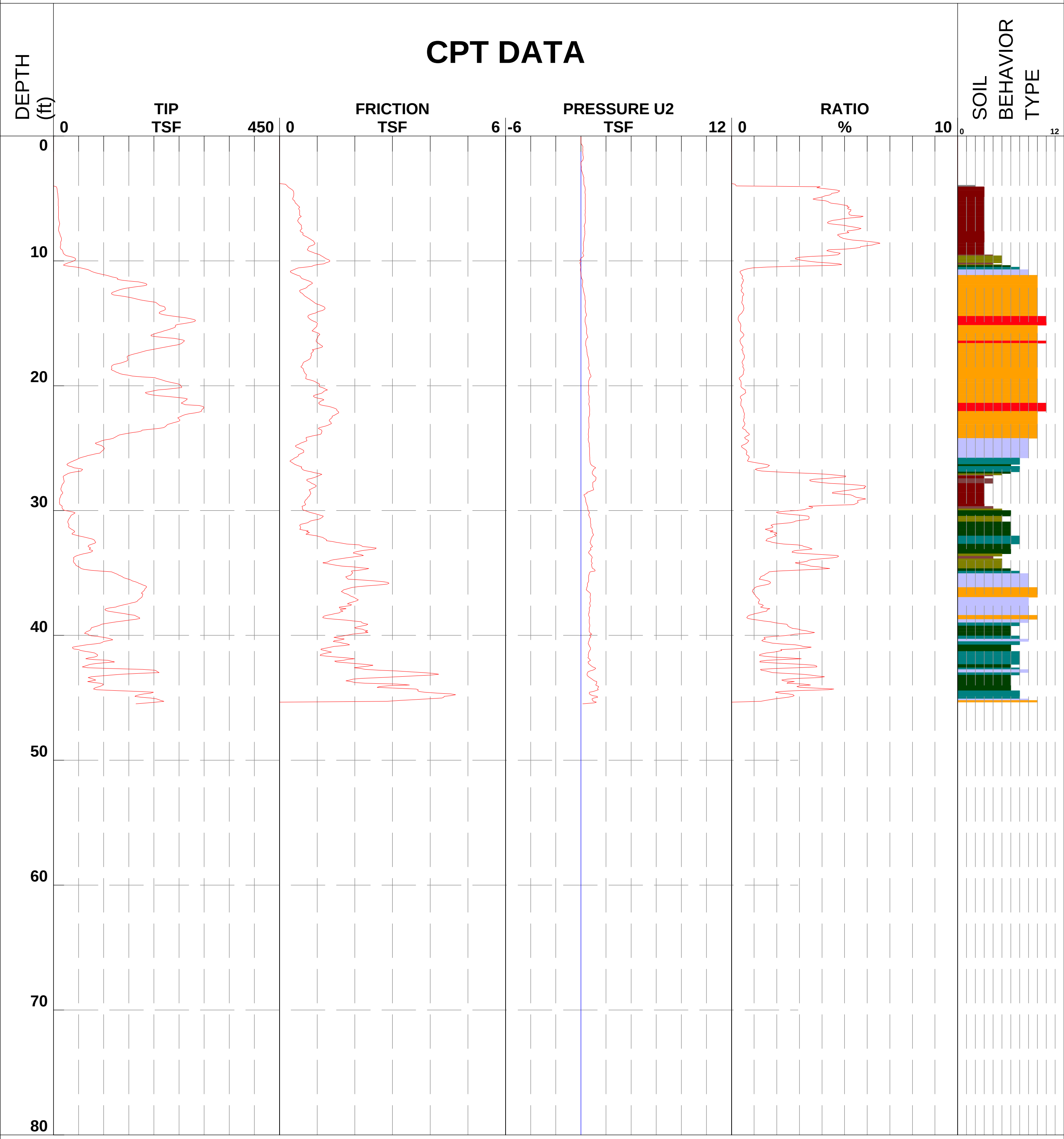
Operator Jared Loviere

Date and Tim 04-Jan-2012 15:18:14

Cone Number A15F2.5CKE2H2112

Client ERM

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

Robertson et al. 1986 * Overconsolidated or Cemented



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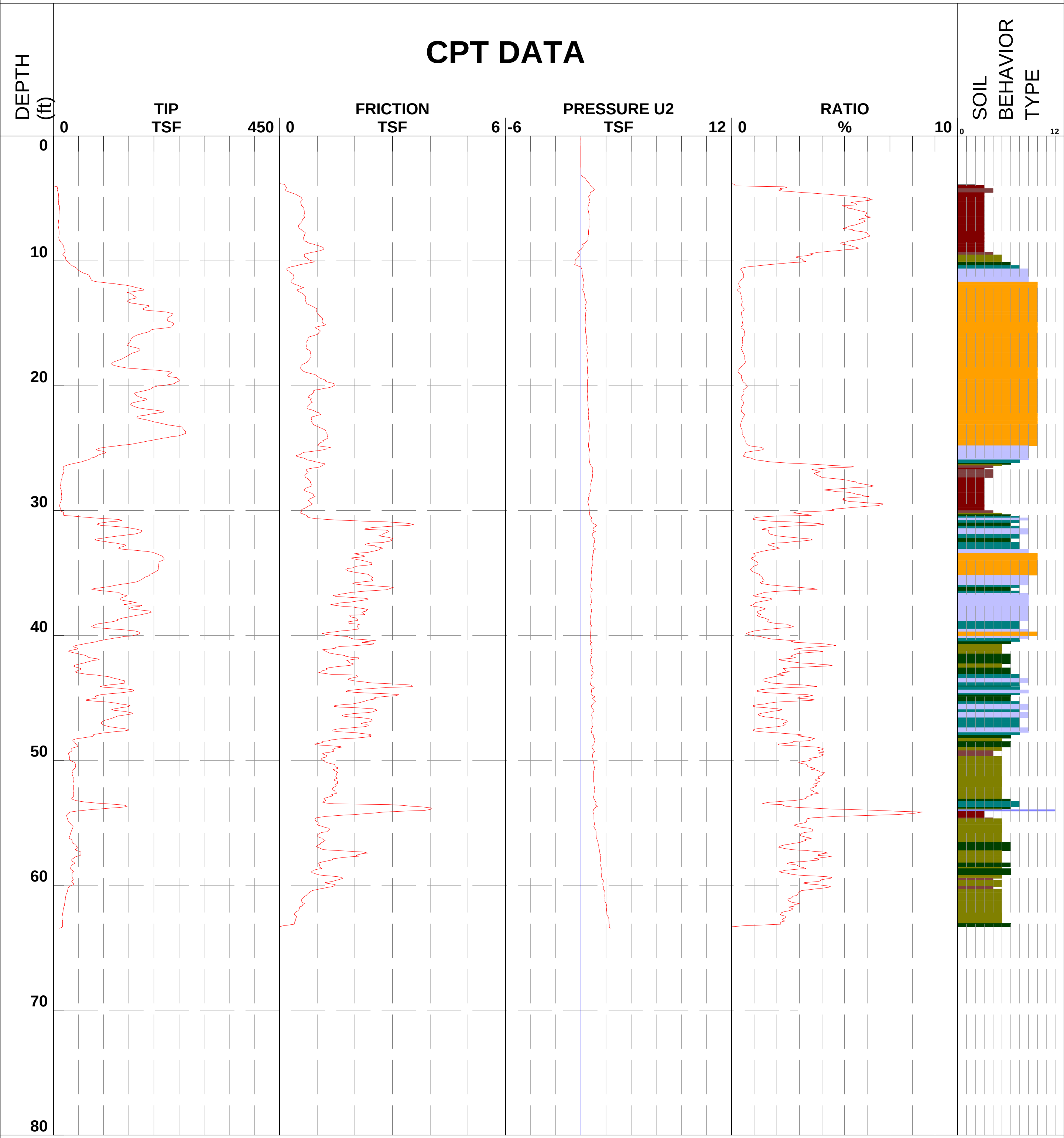
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-C-07
LocatiFormer French Ltd. Site Crosby, TX

Operator Jared Loviere
Date and Tin 21-Dec-2011 15:36:12
Cone Number A15F2.5CKE2H2112

Client ERM

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

Robertson et al. 1986 * Overconsolidated or Cemented

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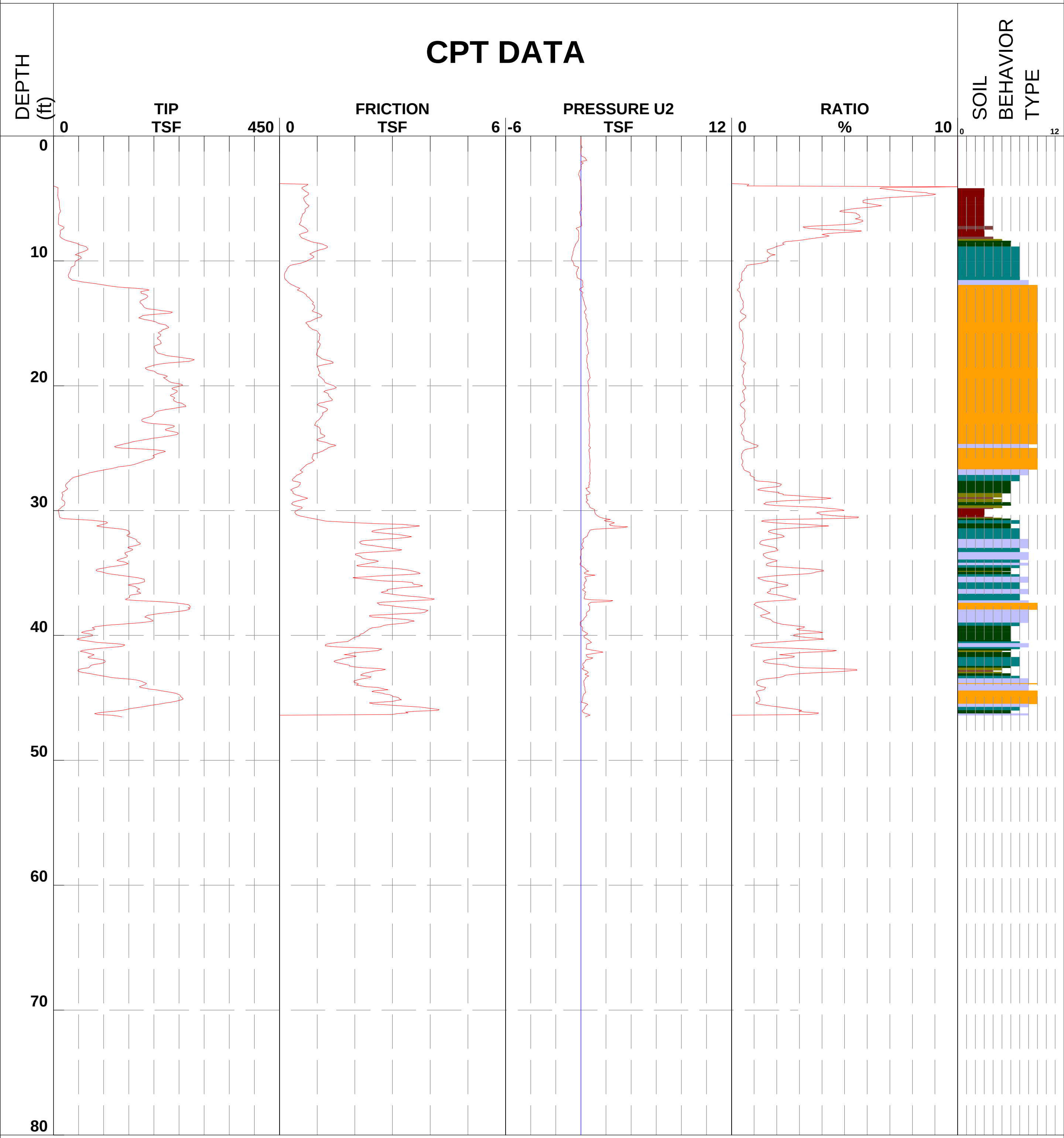
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-C-08
LocatiFormer French Ltd. Site Crosby, TX
Operator Jared Louviere
Date and Tim 04-Jan-2012 13:19:15
Cone Number A15F2.5CKE2H2112
Client ERM

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

Robertson et al. 1986 * Overconsolidated or Cemented



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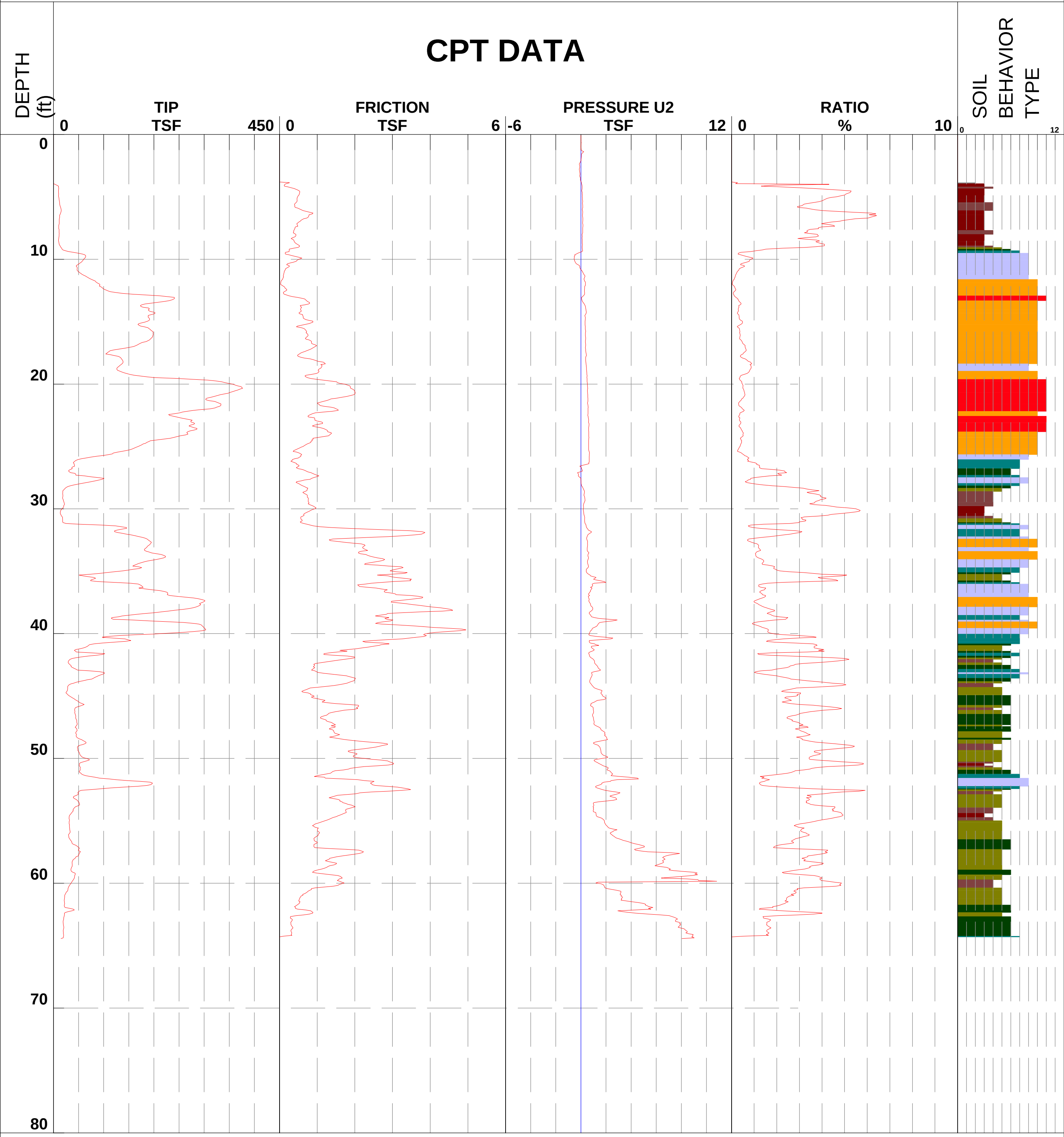
# CPT Data

**Job Number** 04.1911-0063 **CPT Number** MIP-C-09 **LocatiFormer** French Ltd. Site Crosby, TX

**Operator** Jared Loviere **Date and Tim** 03-Jan-2012 08:57:44 **Cone Number** A15F2.5CKE2H2112

**Client** ERM

***4' augered***




| | | | |
|---|---|---|---|
| 1 - sensitive fine grained | 4 - silty clay to clay | 7 - silty sand to sandy silt | 10 - gravelly sand to sand |
| 2 - organic material | 5 - clayey silt to silty clay | 8 - sand to silty sand | 11 - very stiff fine grained (*) |
| 3 - clay | 6 - sandy silt to clayey silt | 9 - sand | 12 - sand to clayey sand (*) |

Robertson et al. 1986 * Overconsolidated or Cemented



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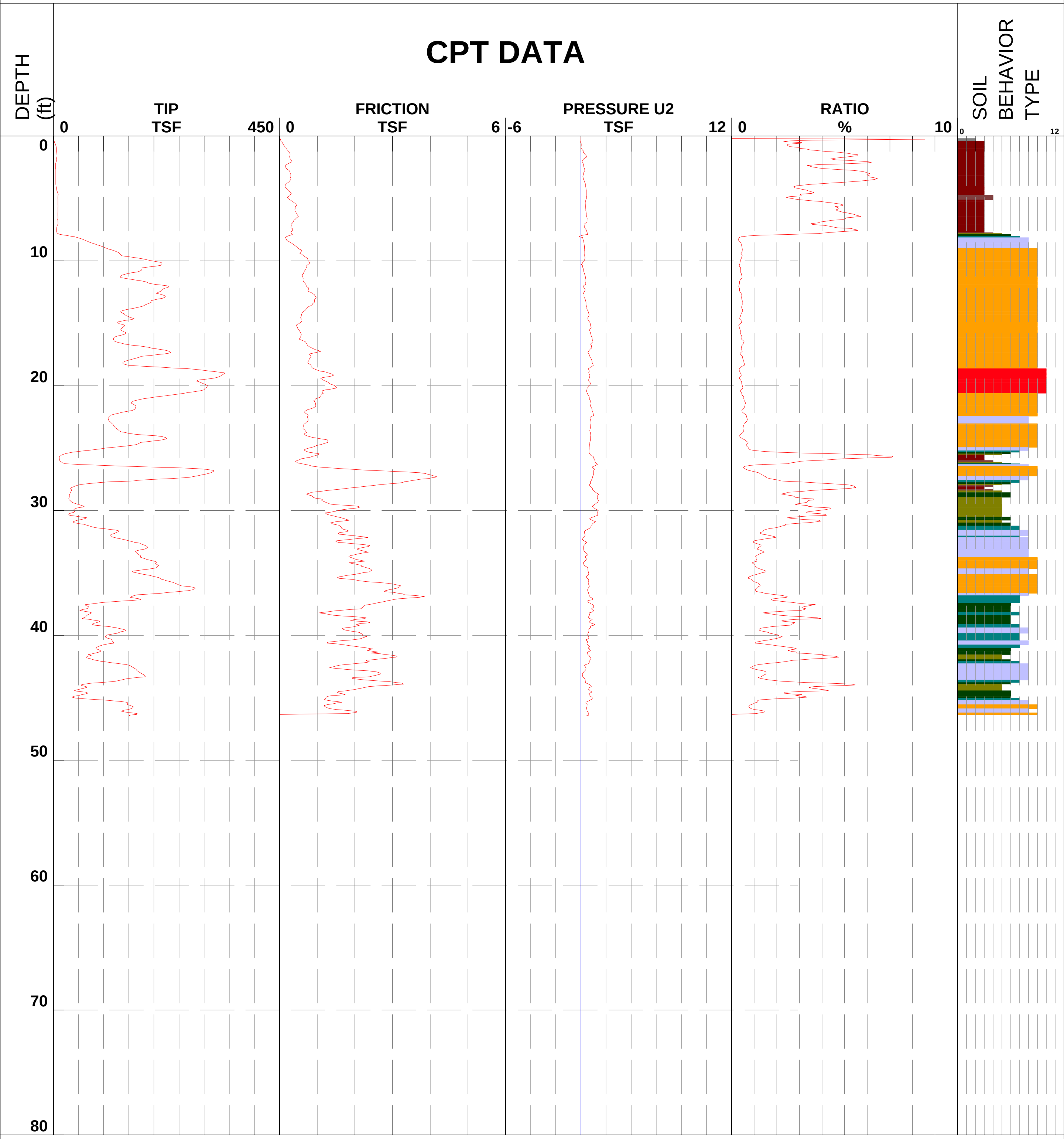
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-D-03
LocatiFormer French Ltd. Site Crosby, TX
Operator Jared Louviere
Date and Tim 06-Jan-2012 07:42:33
Cone Number A15F2.5CKE2H2112
Client ERM




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

Robertson et al. 1986 * Overconsolidated or Cemented

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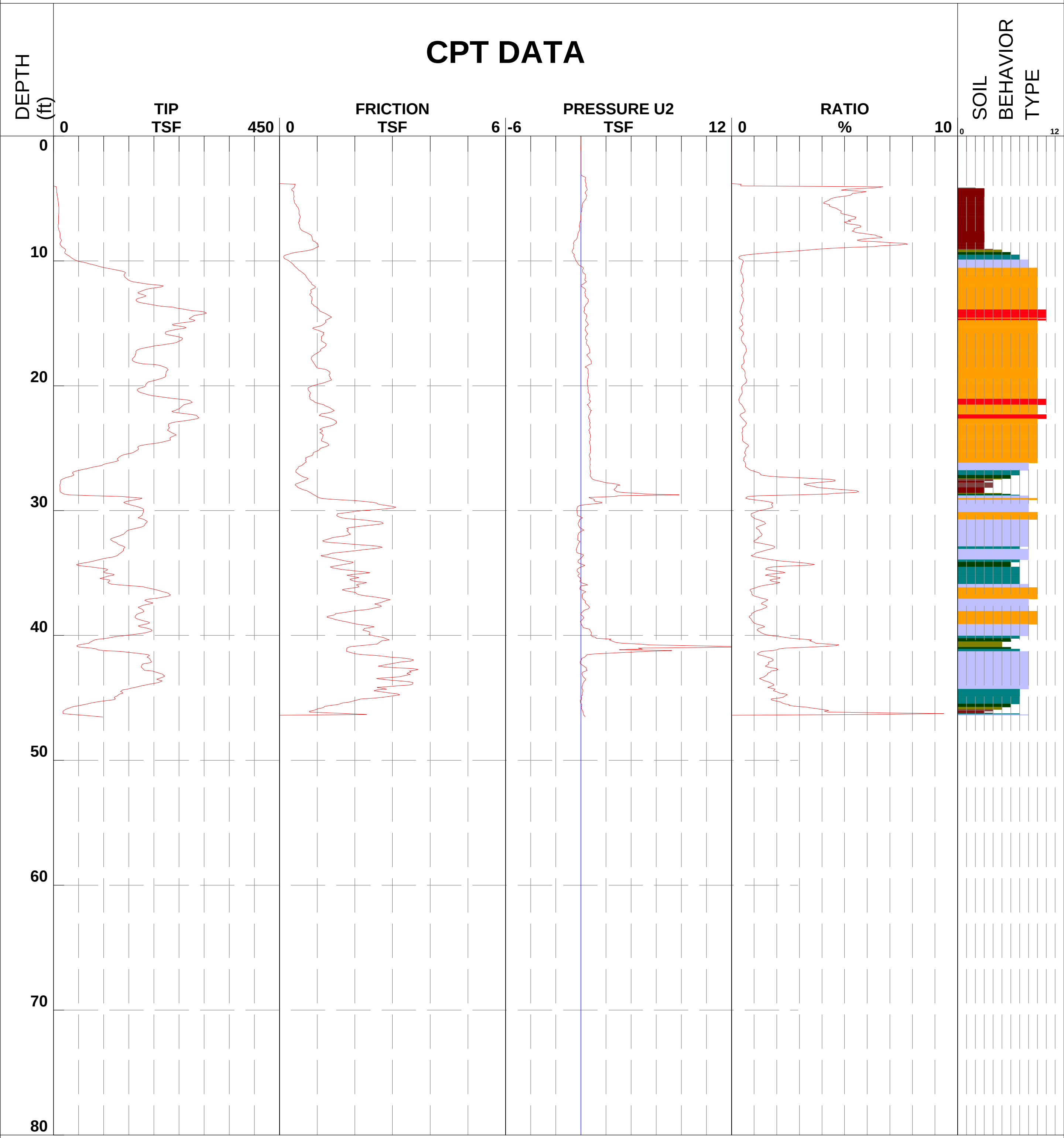
# CPT Data

Job Number 04.1911-0063
CPT Number MIP-E-05
LocatiFormer French Ltd. Site Crosby, TX
Operator Jared Louviere
Date and Tim 05-Jan-2012 15:01:04
Cone Number A15F2.5CKE2H2112
Client ERM

***4' augered***




1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

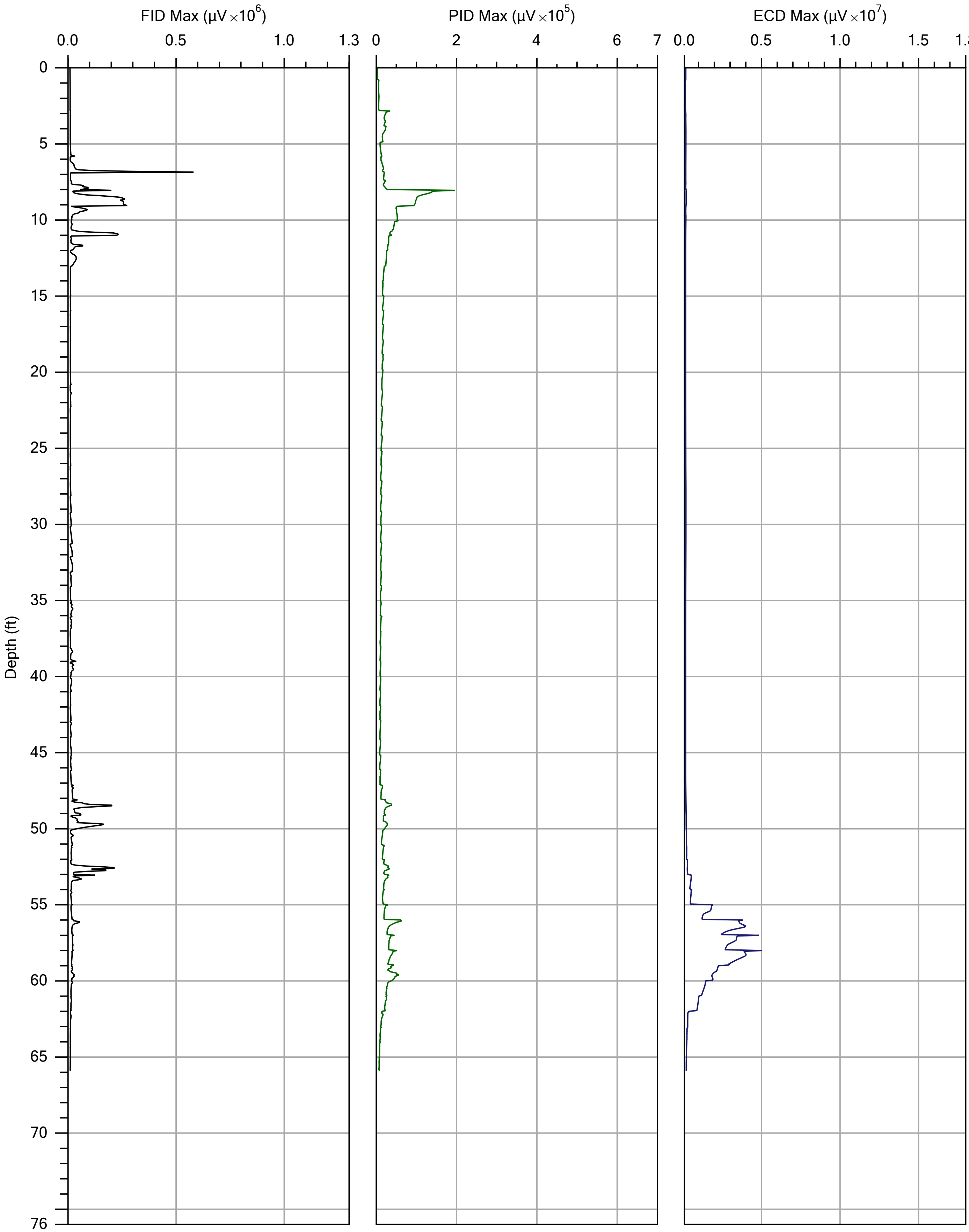
Robertson et al. 1986 * Overconsolidated or Cemented

# Membrane Interface Probe (MIP) Logs

*Appendix C*

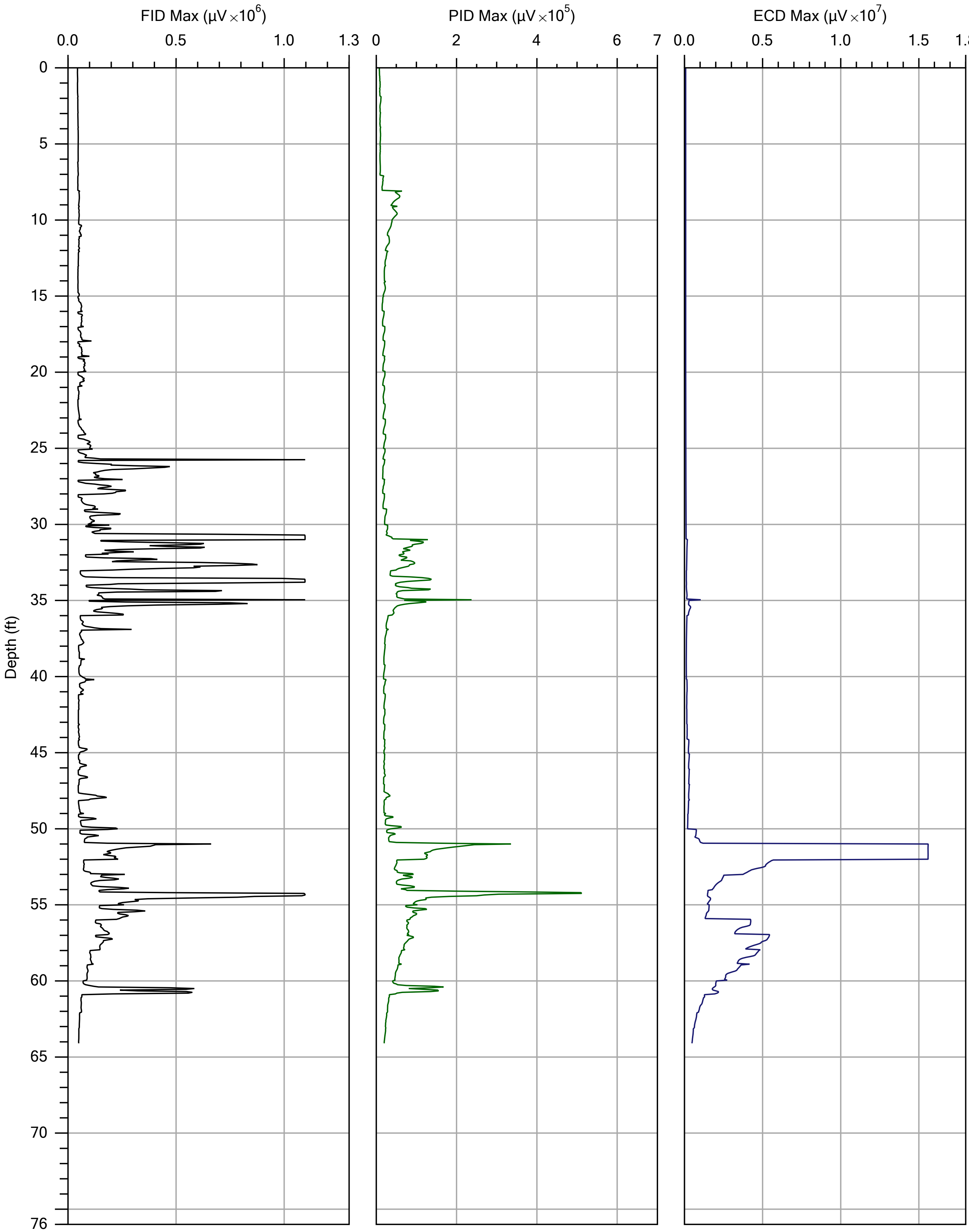
*April 2, 2014*
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000



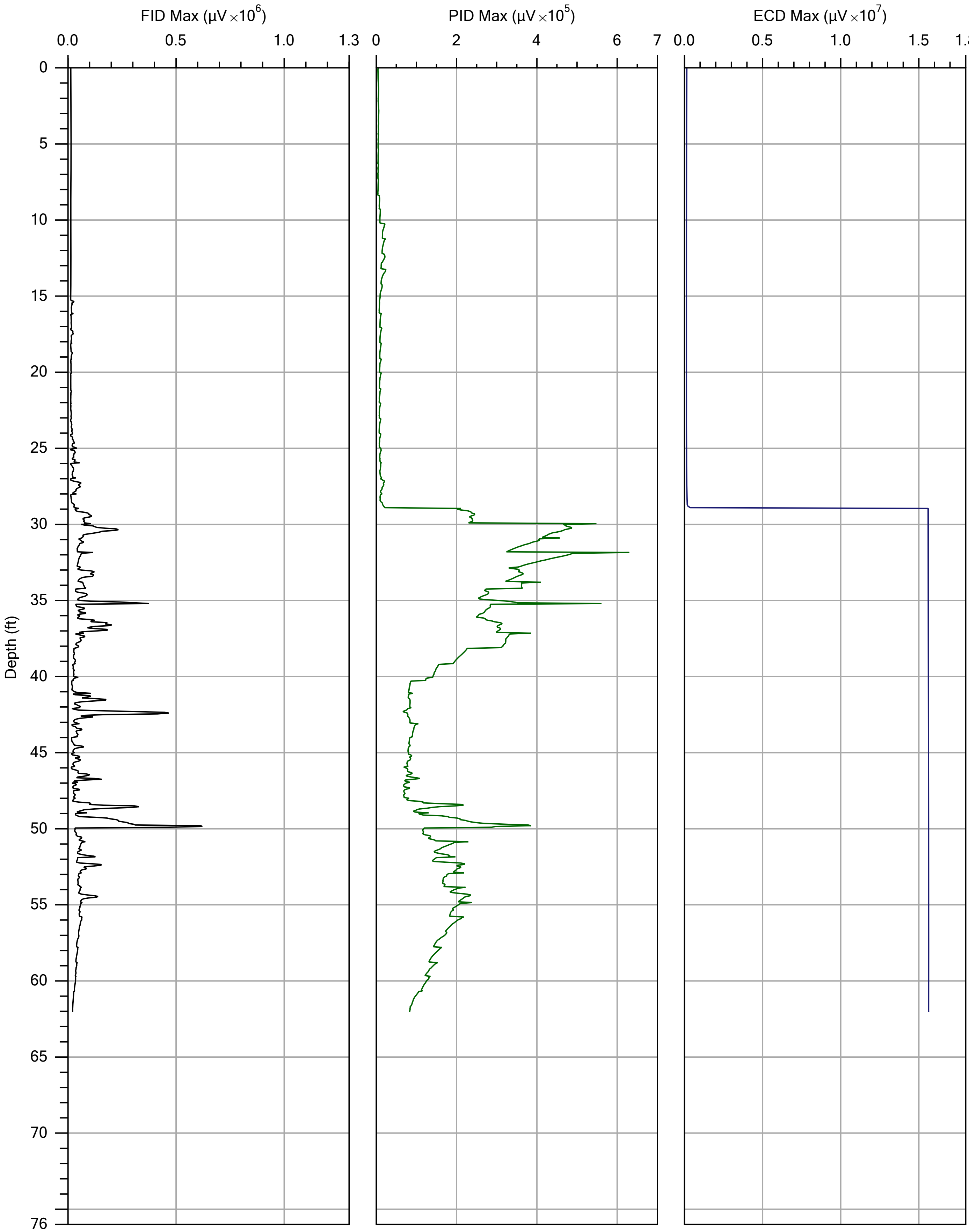

FUGRO

| | | |
|---|---|---|
| | | File: MIP-A-01.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 12/20/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



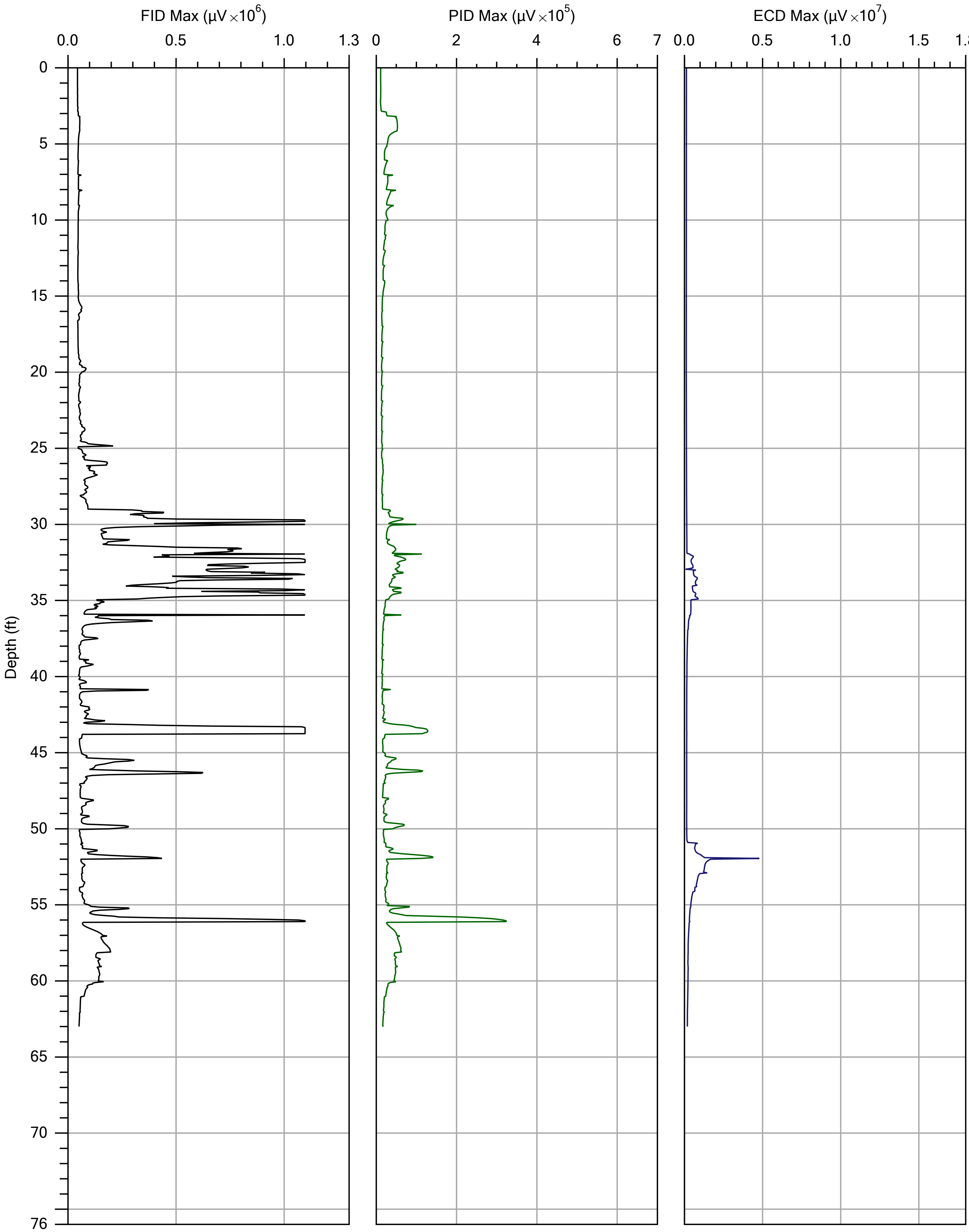

FUGRO

| File: MIP-A-02A.MIP | | |
|---|---|---|
| Company: ERM | Operator: Albert Fonseca | Date: 1/10/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



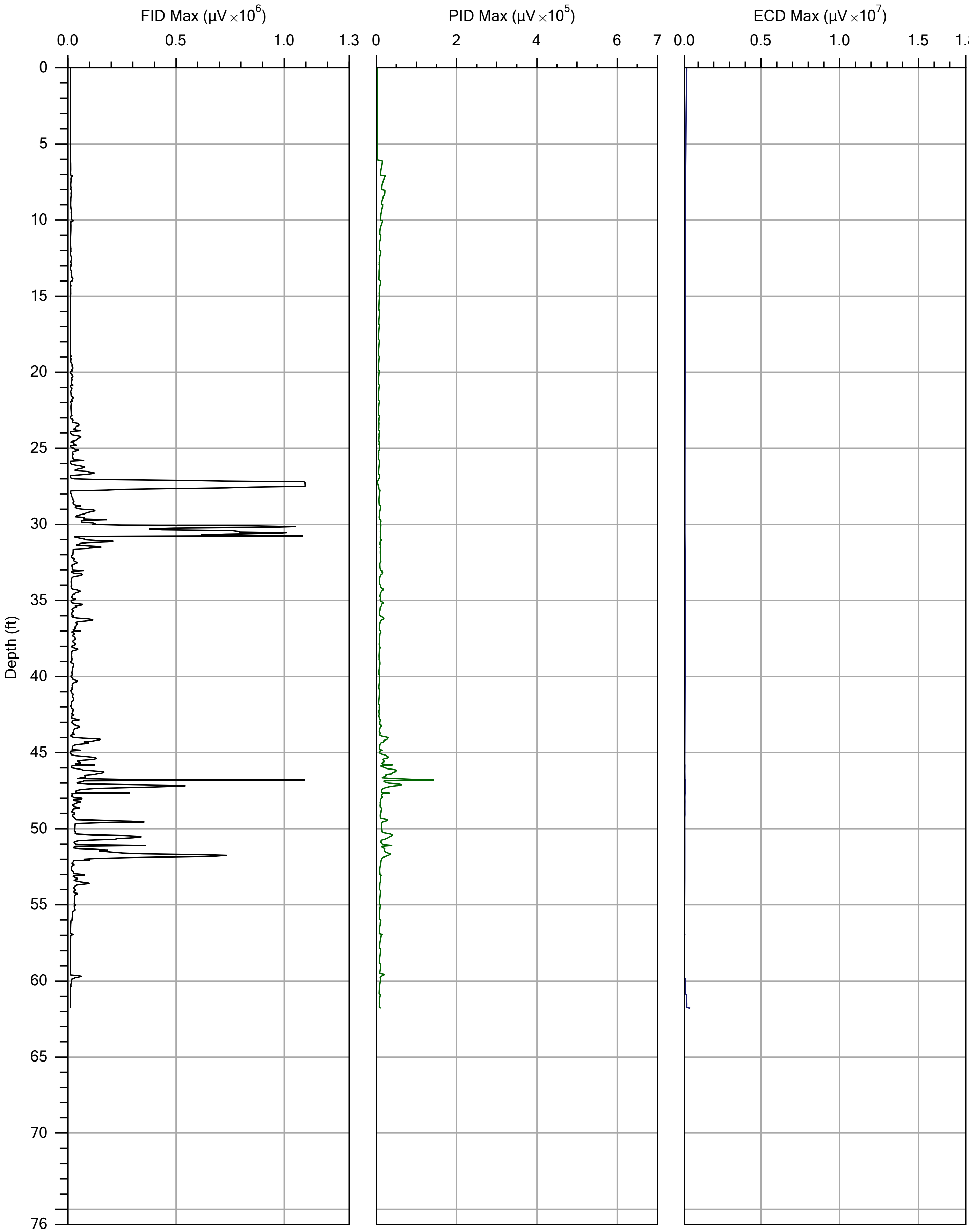

FUGRO

| | | |
|---|---|---|
| | | File: MIP-A-03.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 12/19/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



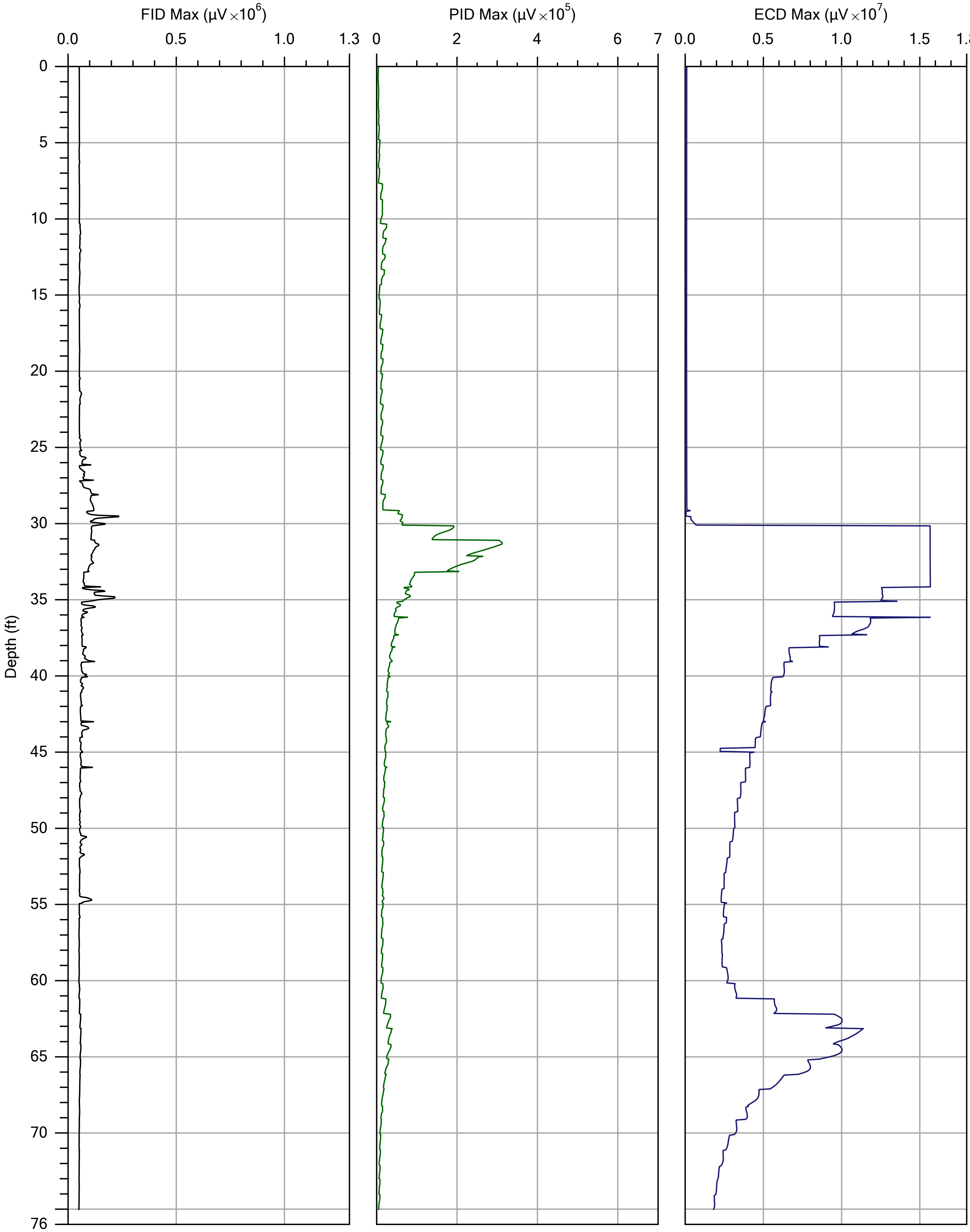

FUGRO

| | | |
|---|---|---|
| | | File: MIP-A-04.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/10/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |

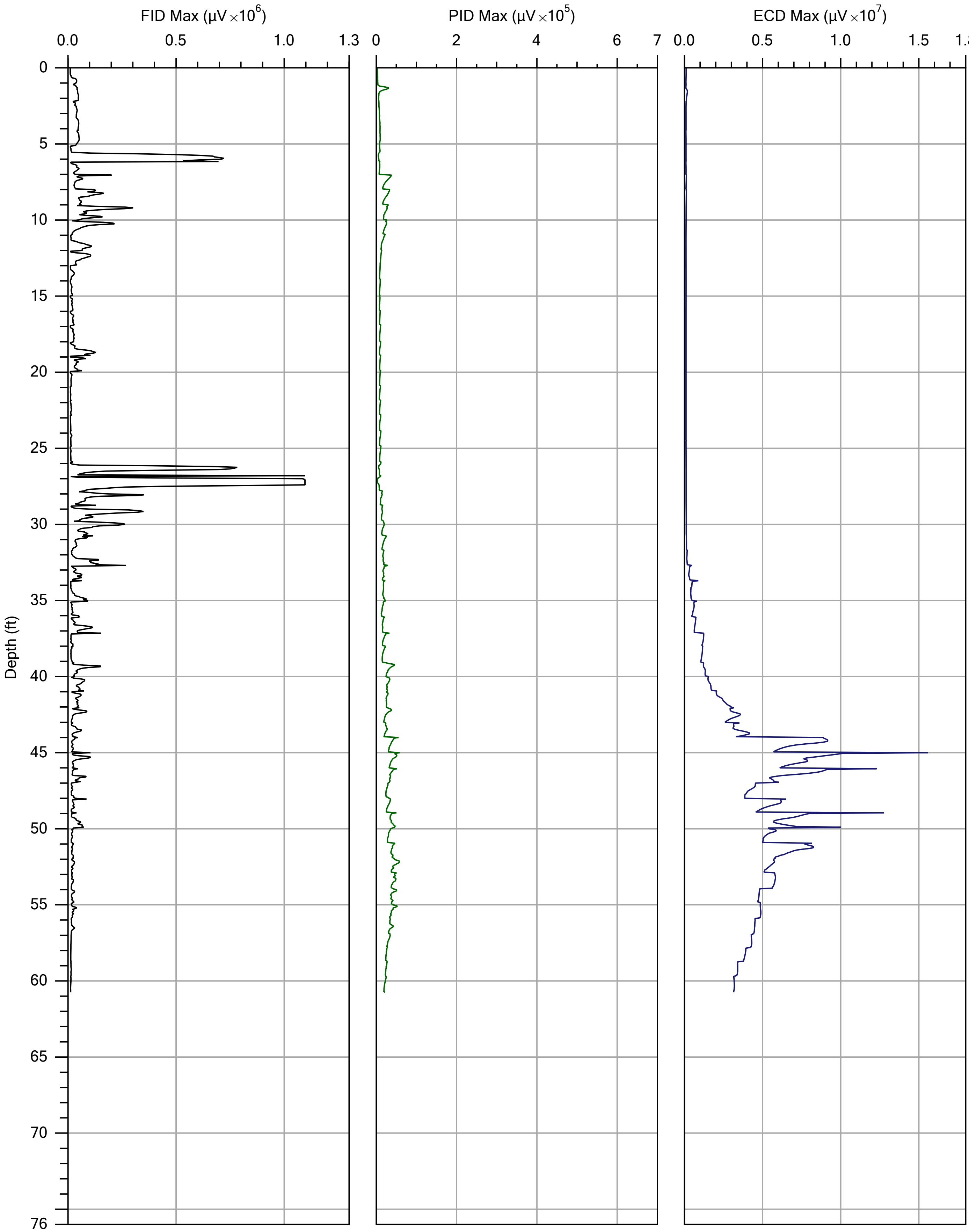



FUGRO

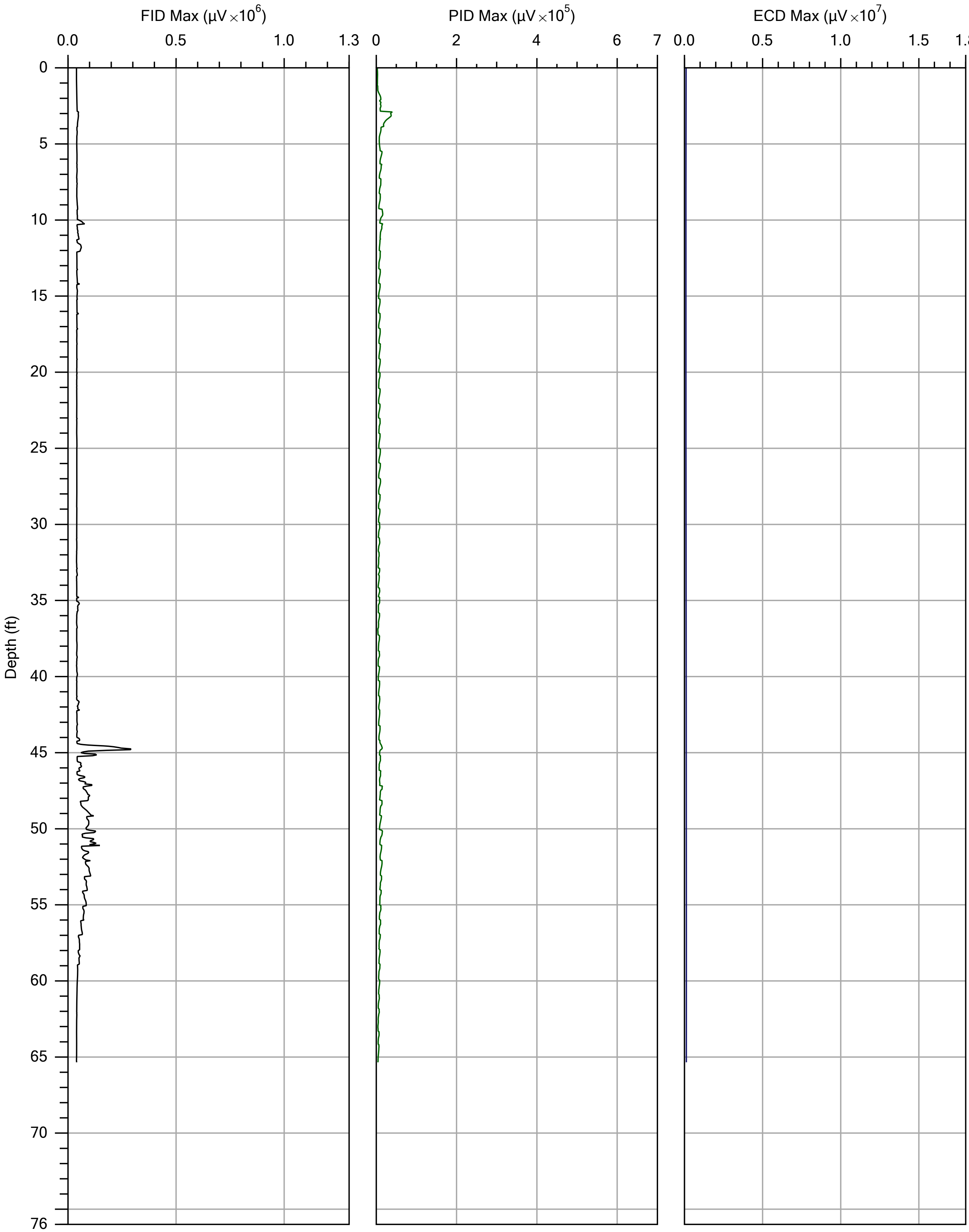
| | | |
|---|---|---|
| | | File: MIP-A-05.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 12/19/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



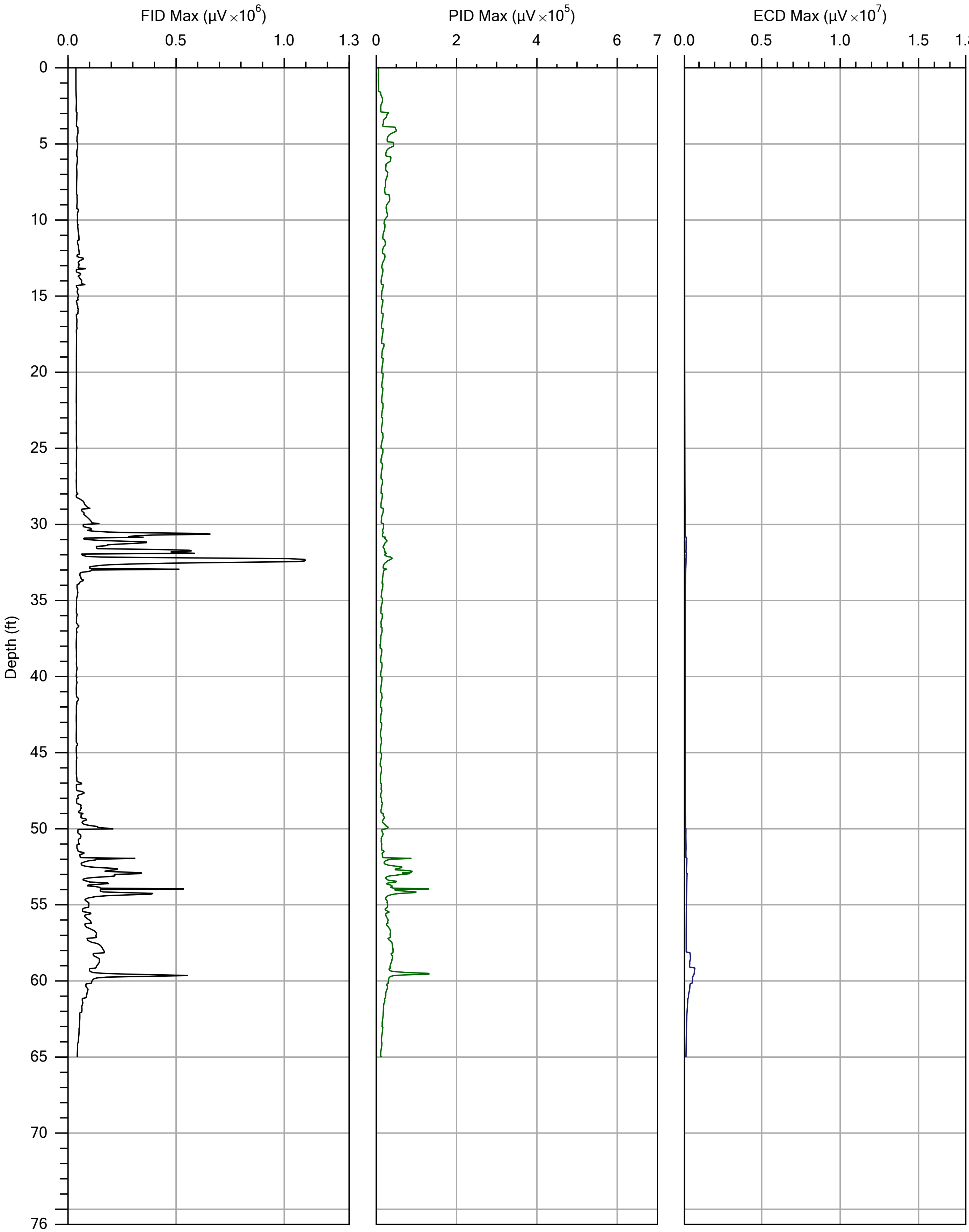

| Company: ERM | Operator: Albert Fonseca | File: MIP-A-06.MIP |
|---|---|---|
| | | Date: 1/5/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



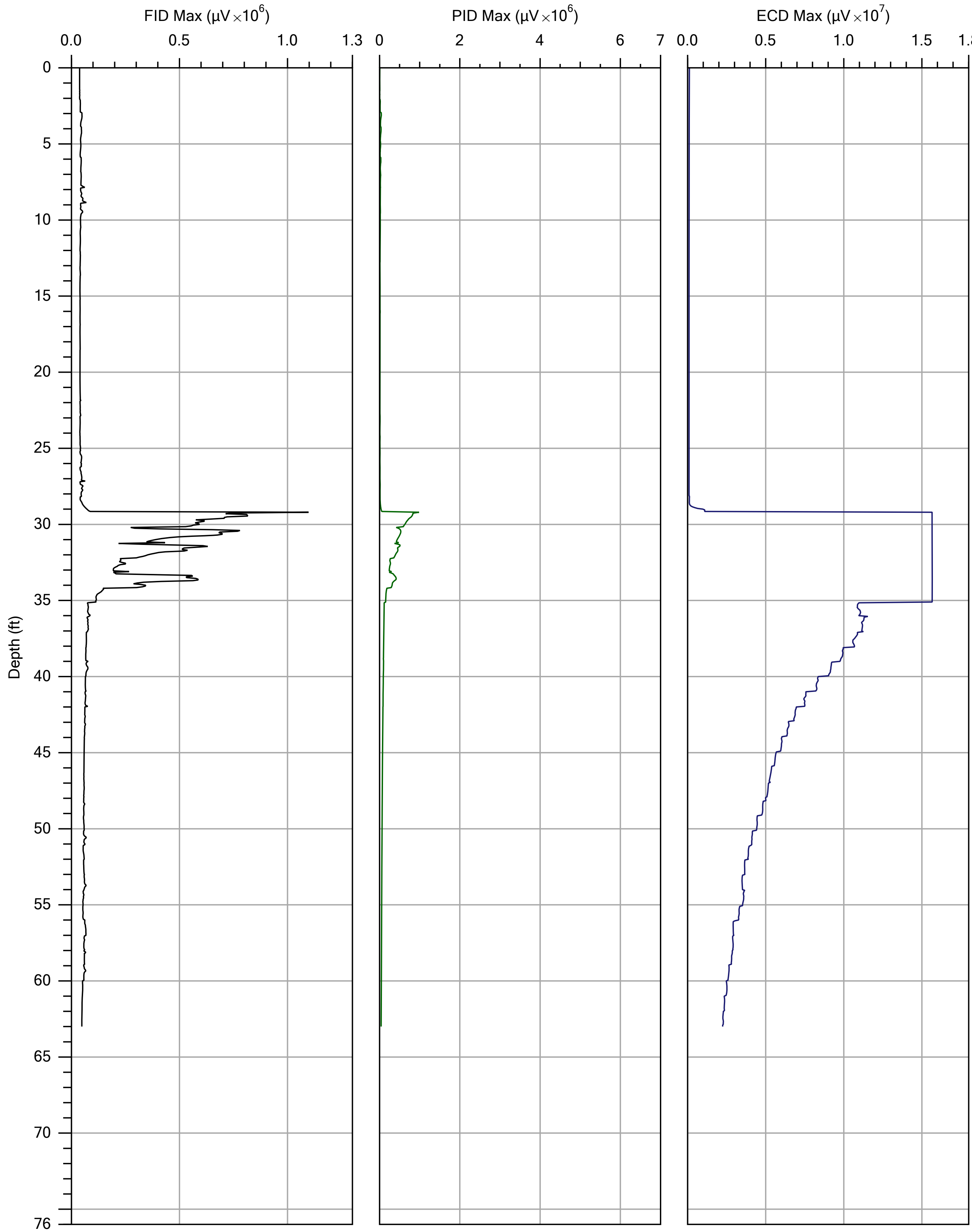

| | | |
|---|---|---|
| | | File: MIP-A-07.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 12/19/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



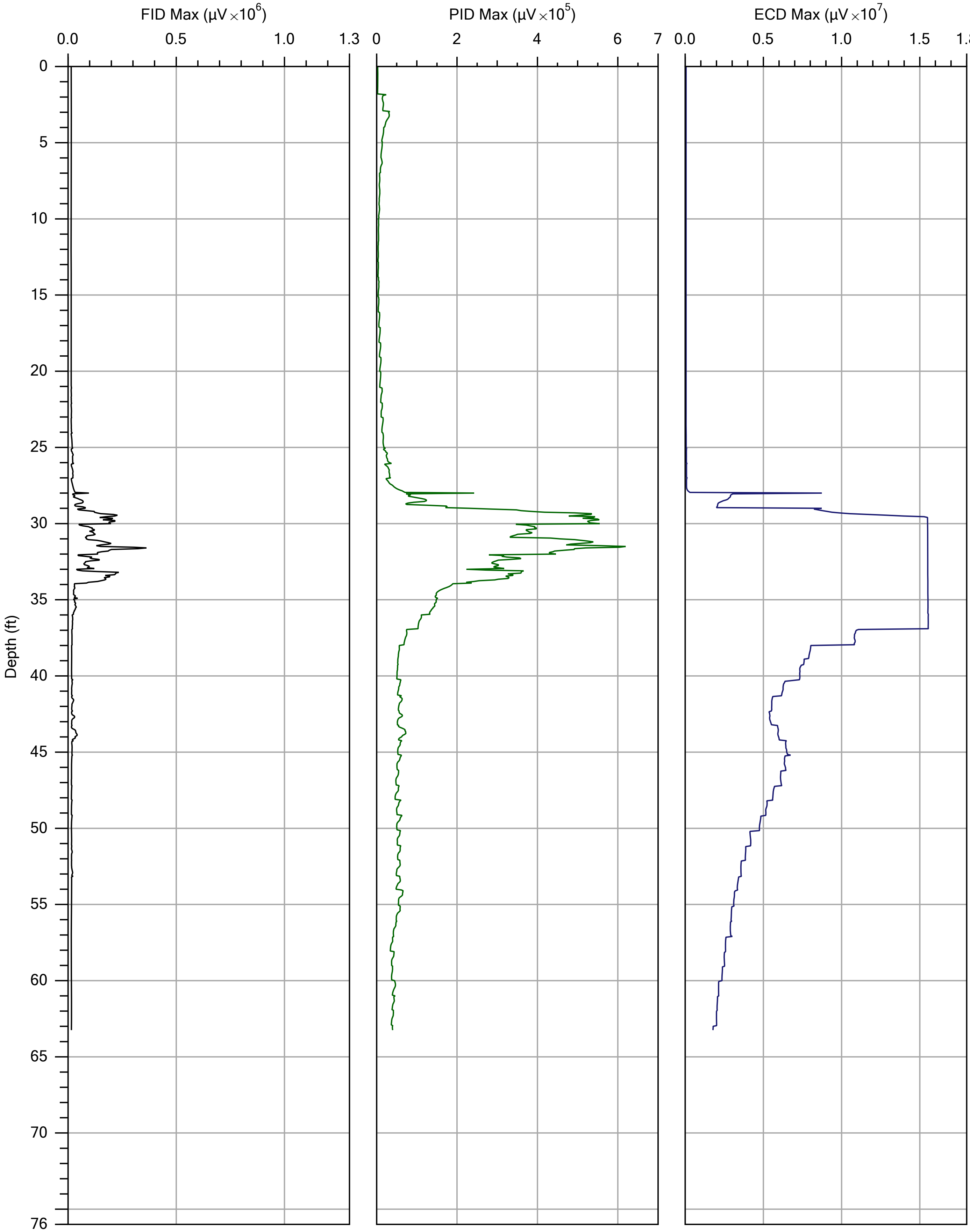

| | | |
|---|---|---|
| | | File: MIP-B-01.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/6/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



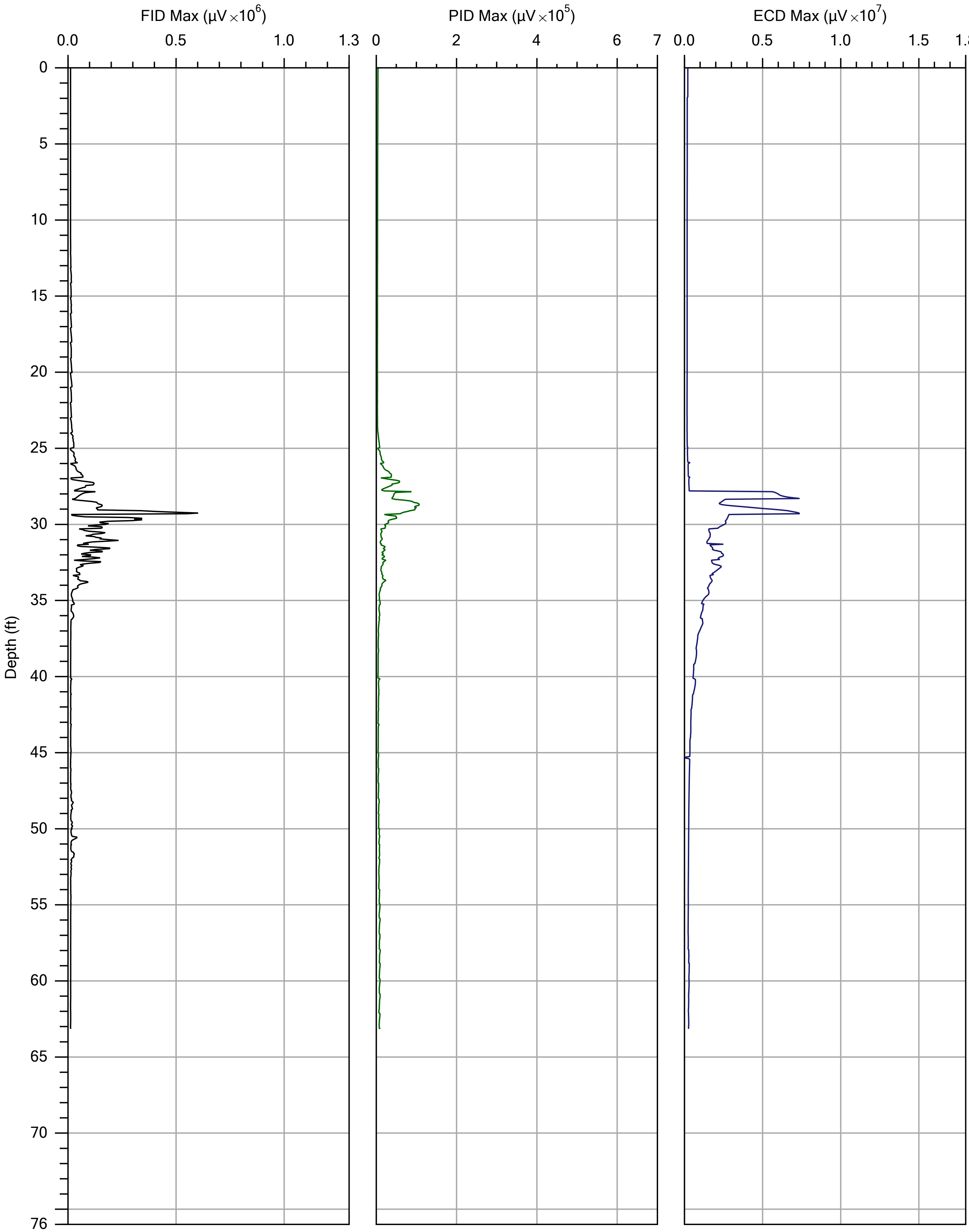

| Company: ERM | Operator: Albert Fonseca | File: MIP-B-02.MIP<br>Date: 1/6/2012 |
|---|---|---|
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |




| | | |
|---|---|---|
| | | File: MIP-B-03.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/6/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |

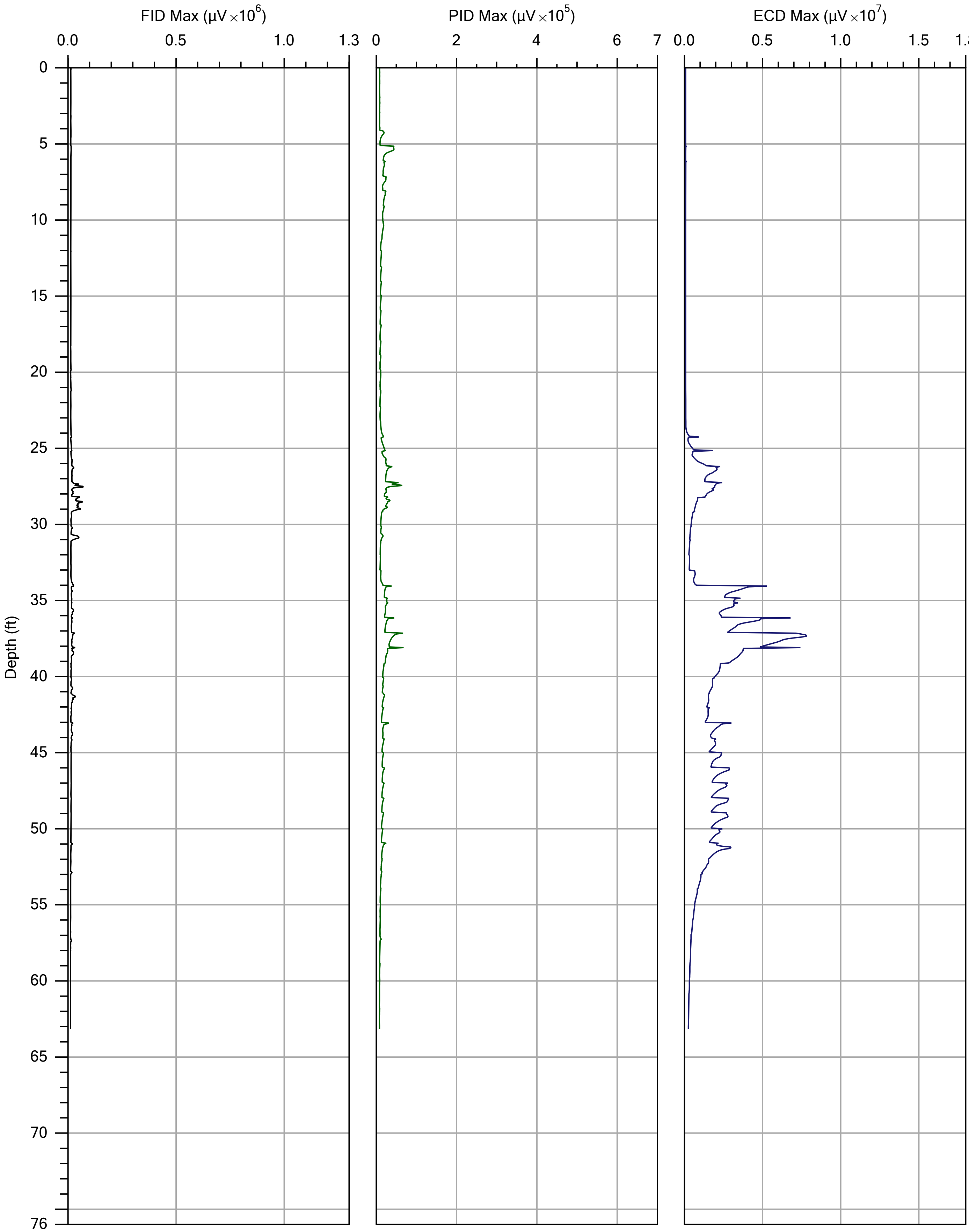



| Company: ERM | Operator: Albert Fonseca | File: MIP-B-04.MIP |
|---|---|---|
| | | Date: 1/4/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |

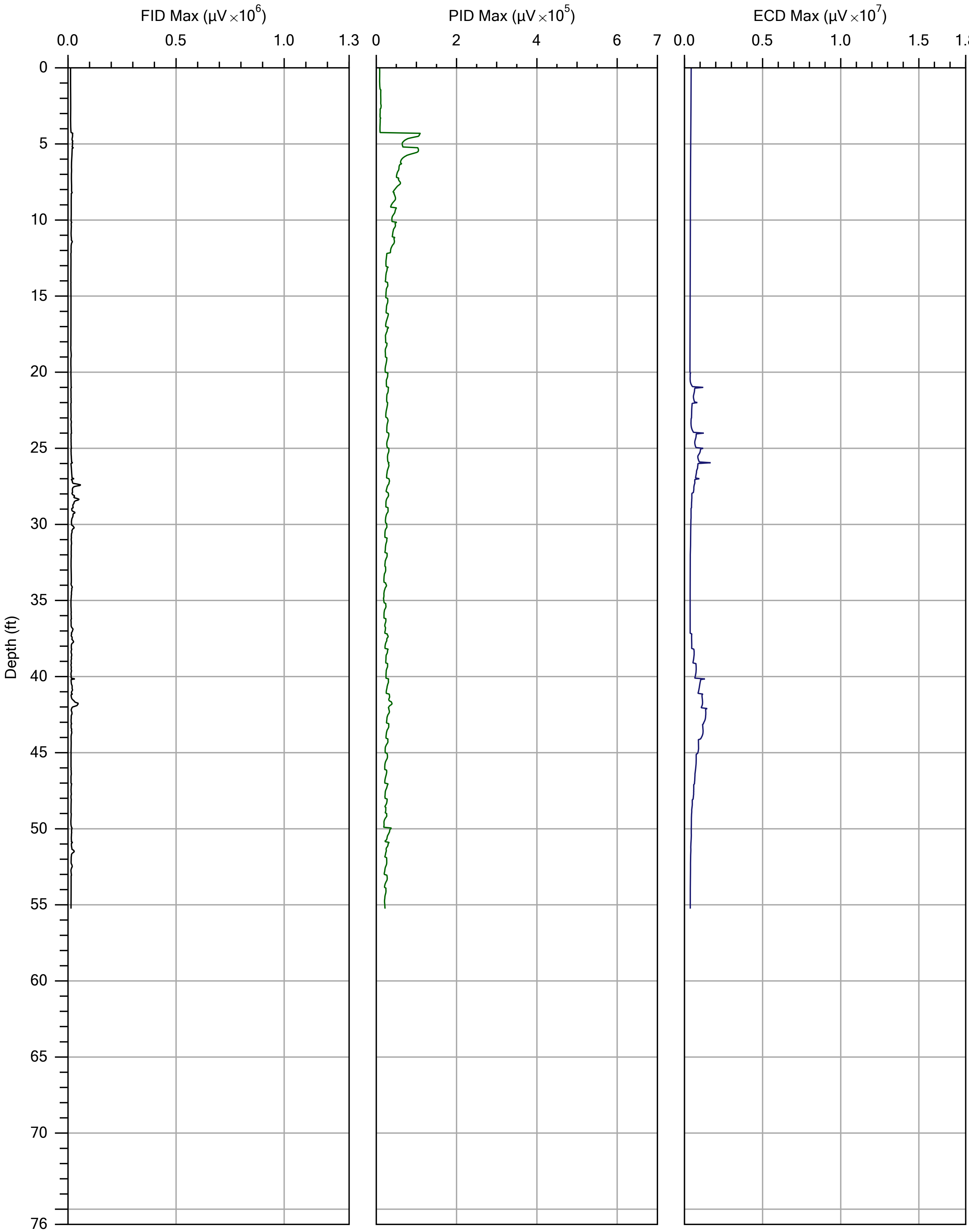



FUGRO

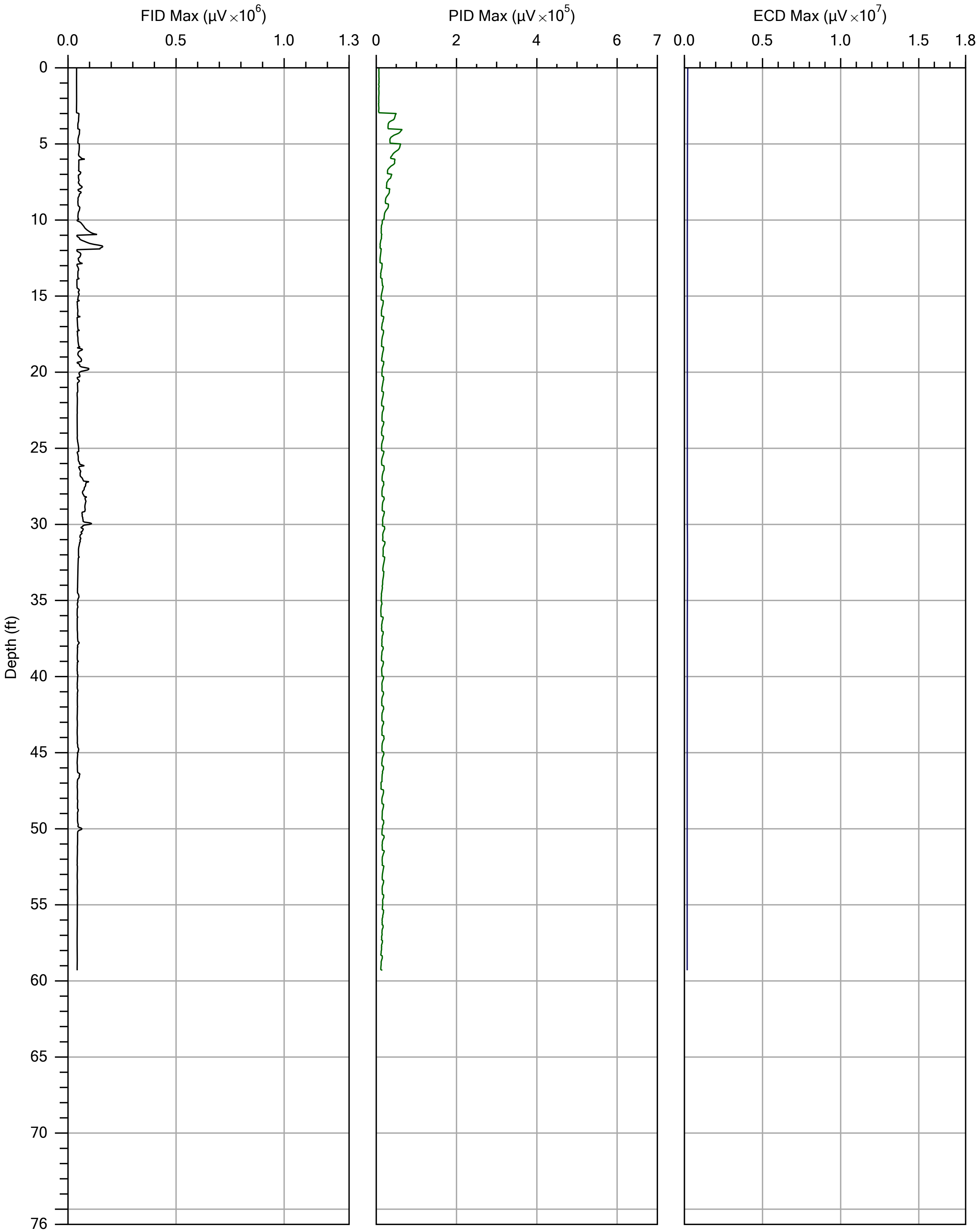
| Company: ERM | Operator: Albert Fonseca | File: MIP-B-05.MIP |
|---|---|---|
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Date: 1/3/2012 |
| | | Location: Crosby, TX |



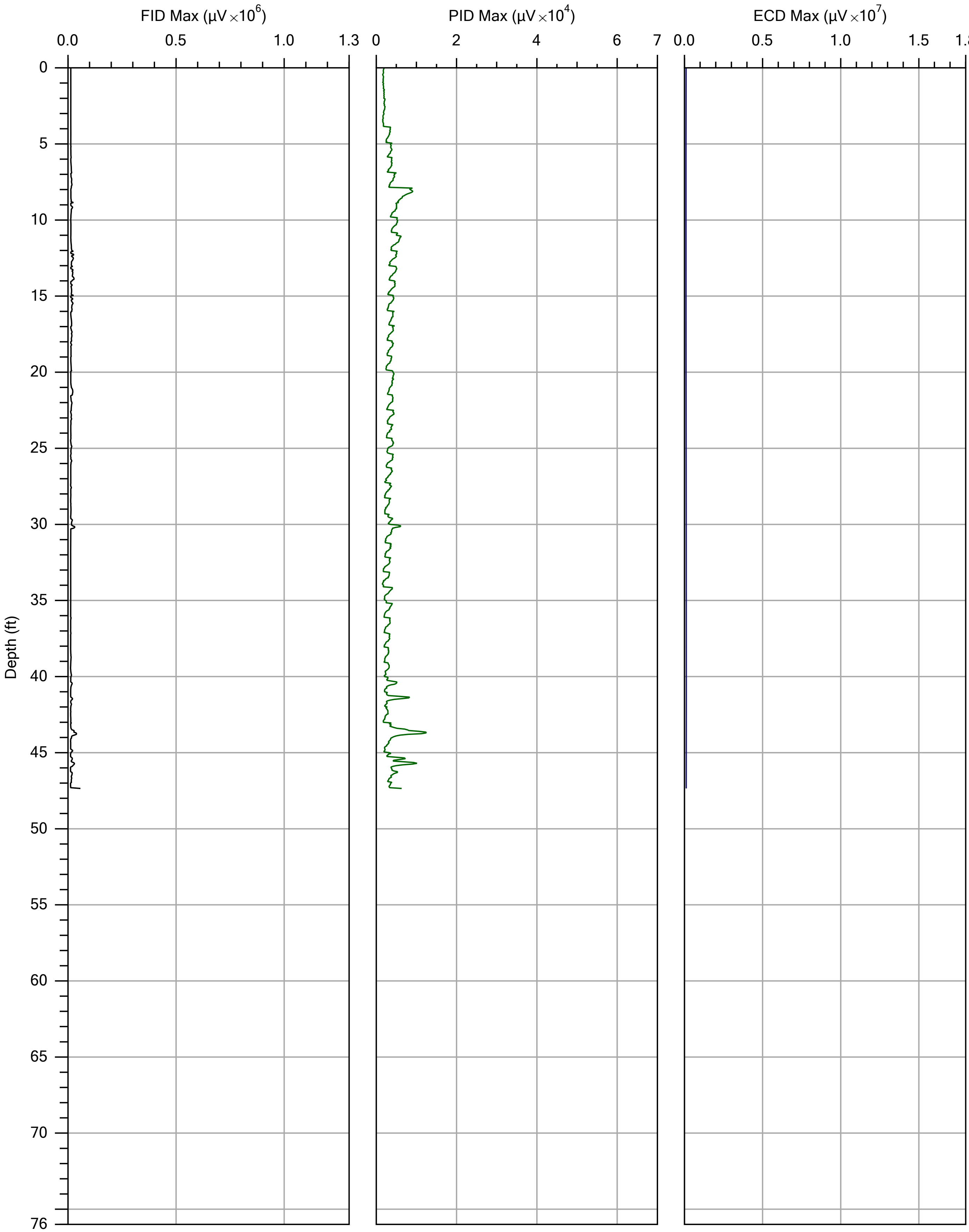

| Company: ERM | Operator: Albert Fonseca | File: MIP-B-06.MIP |
|---|---|---|
| | | Date: 1/3/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



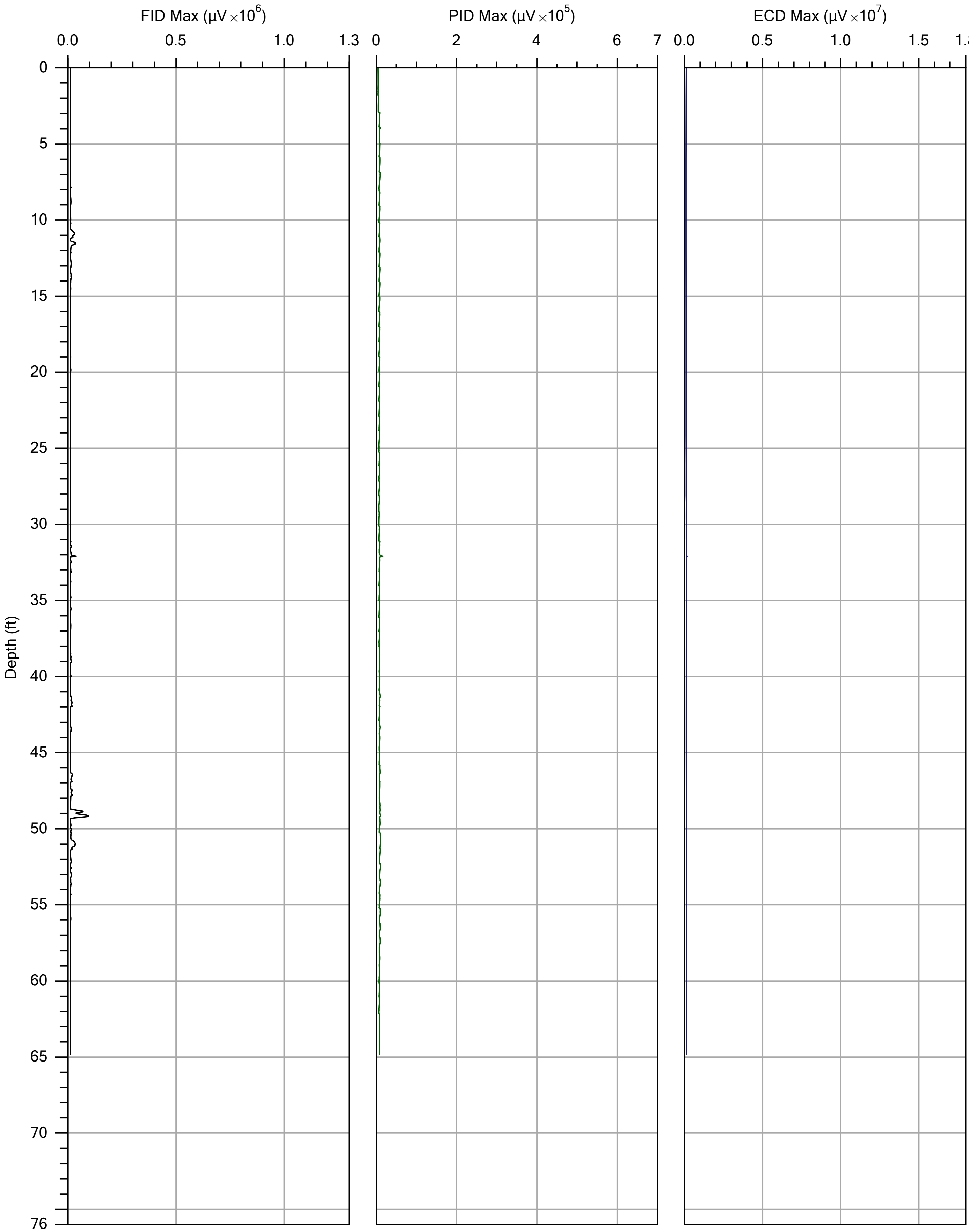

| | | |
|---|---|---|
| | | File: MIP-B-07.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/4/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |




| Company: ERM | Operator: Albert Fonseca | File: MIP-B-08.MIP |
|---|---|---|
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Date: 1/5/2012 |
| | | Location: Crosby, TX |

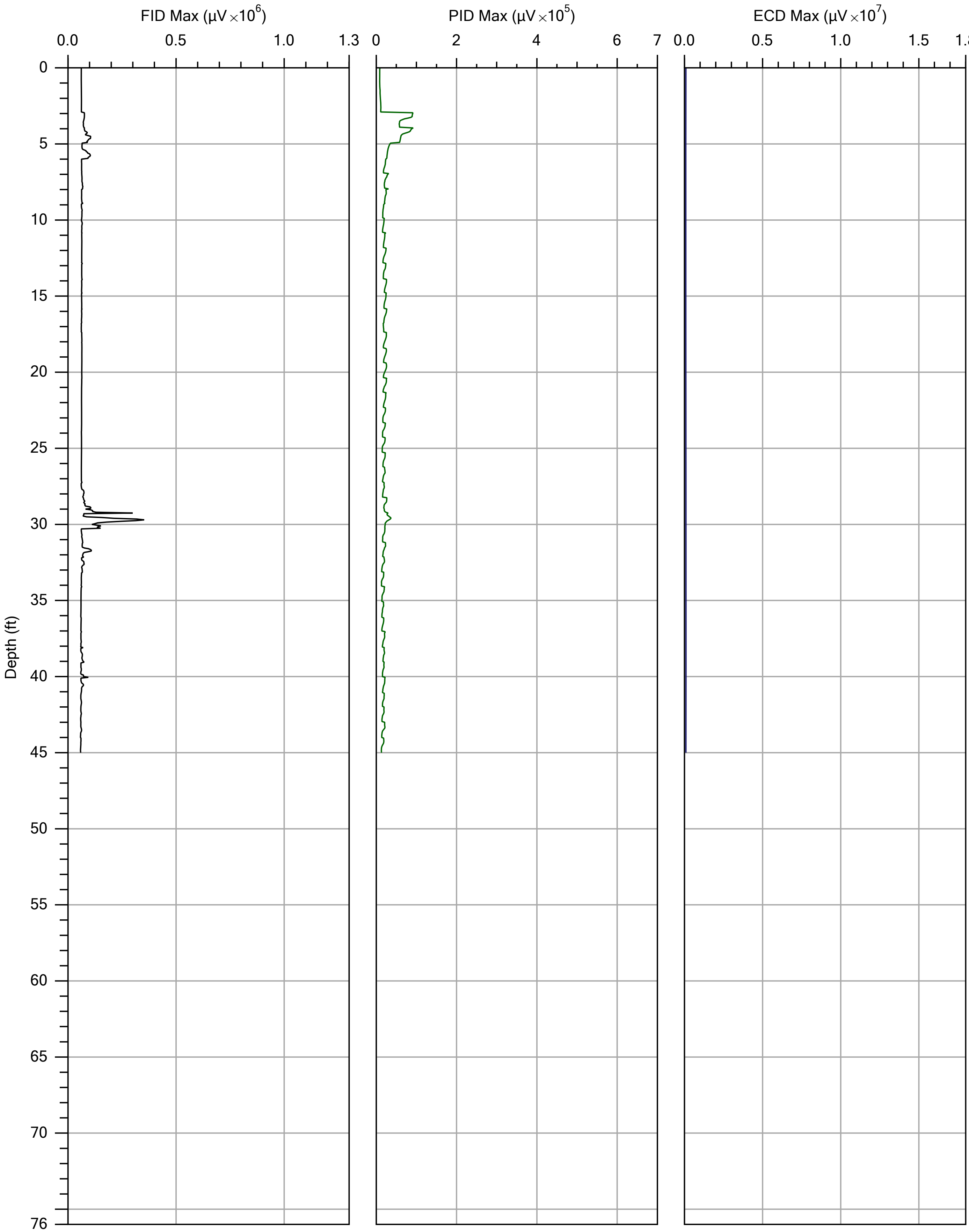



| | | |
|---|---|---|
| | | File: MIP-C-01.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 12/21/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |

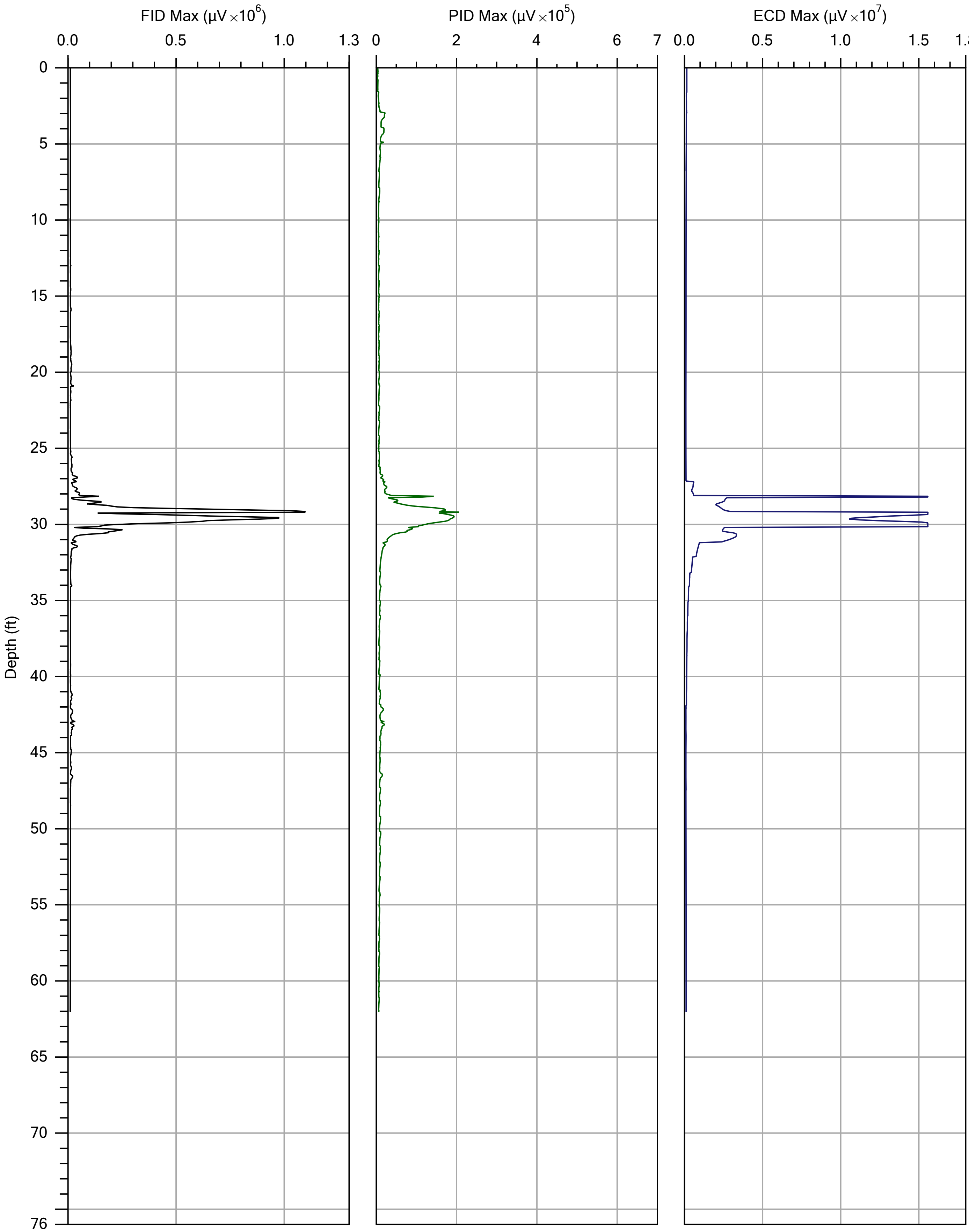



FUGRO

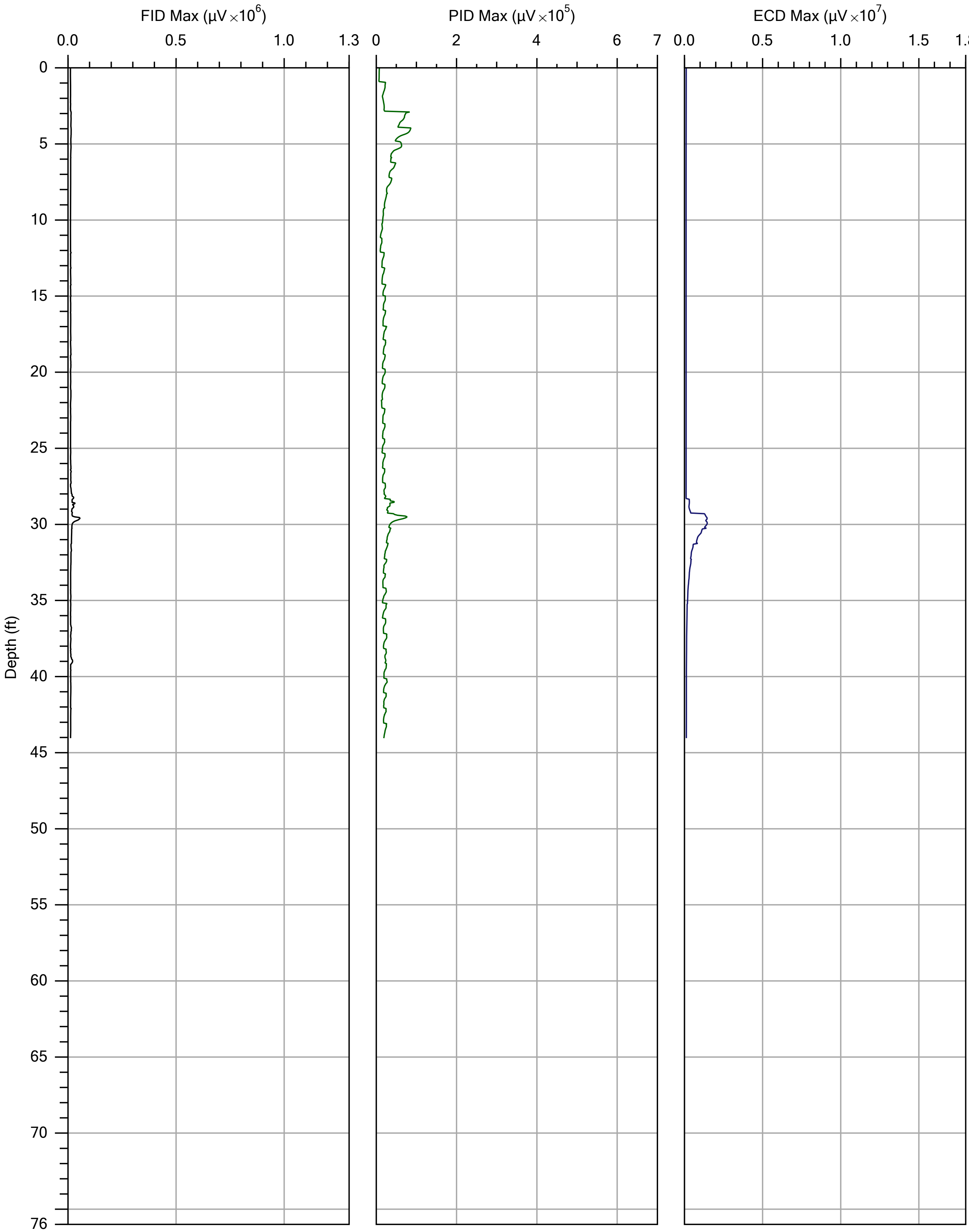
| | | |
|---|---|---|
| | | File: MIP-C-03.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 12/21/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



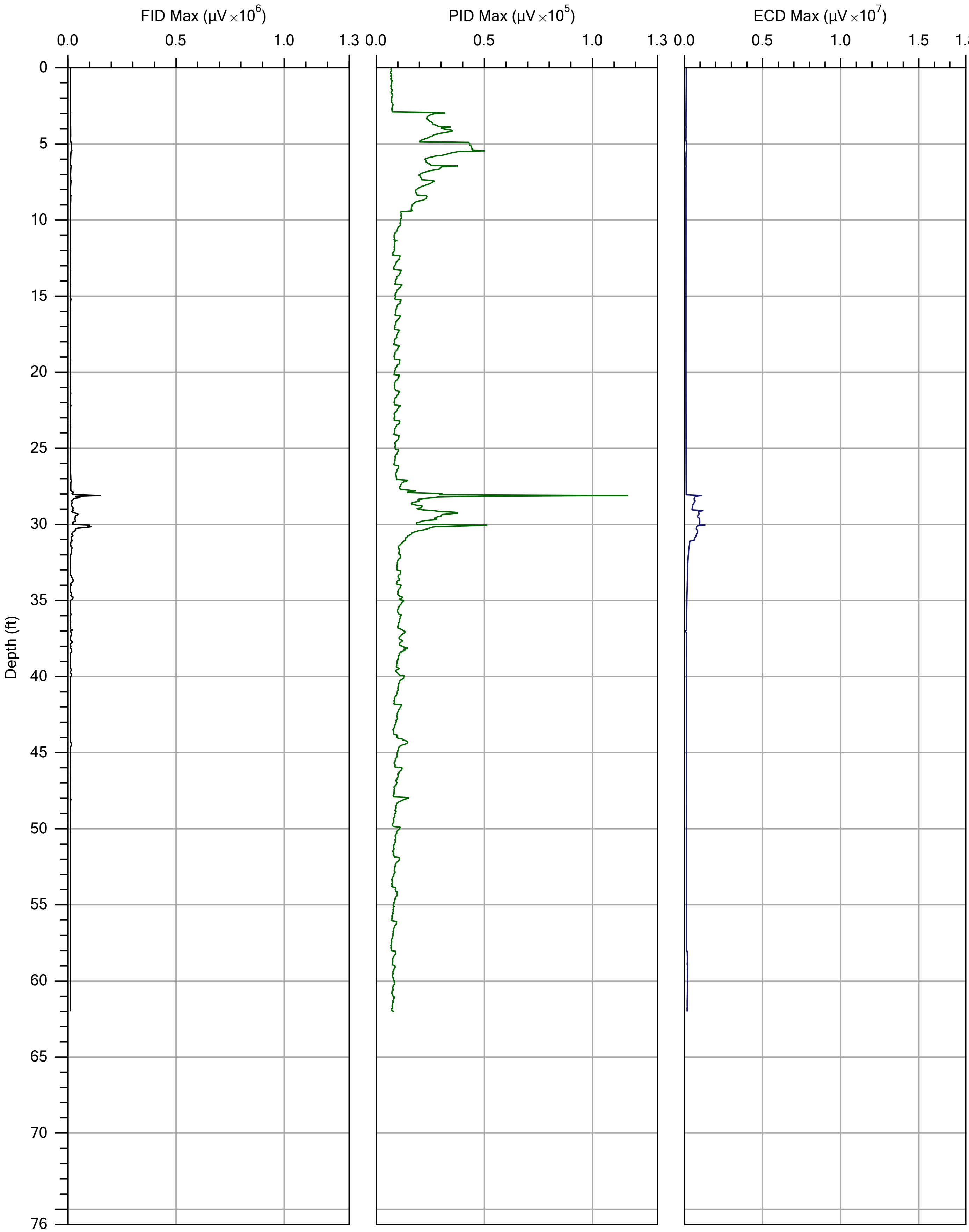

| | | |
|---|---|---|
| | | File: MIP-C-04.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/5/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



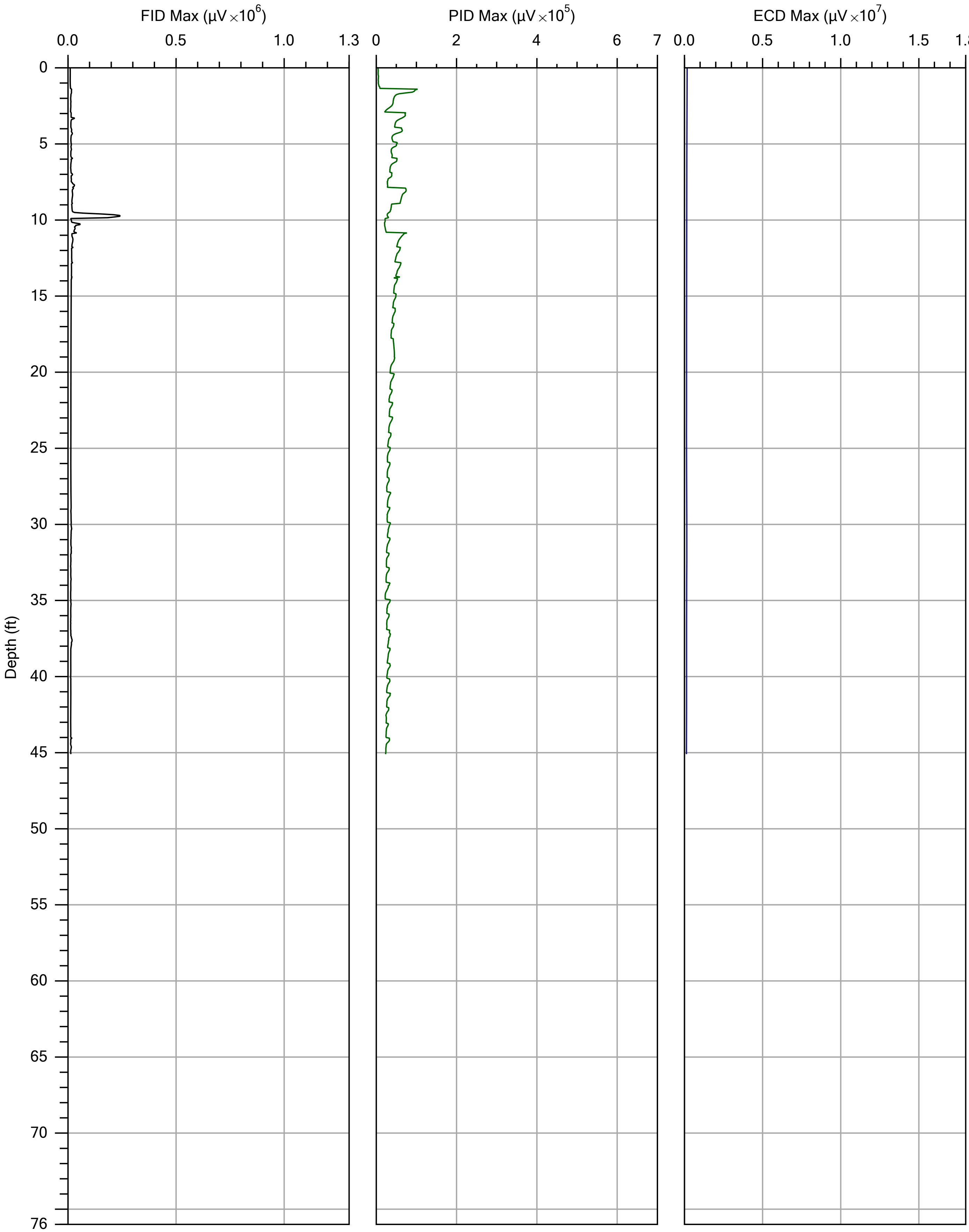

| Company: ERM | Operator: Albert Fonseca | File: MIP-C-05.MIP |
|---|---|---|
| | | Date: 12/21/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



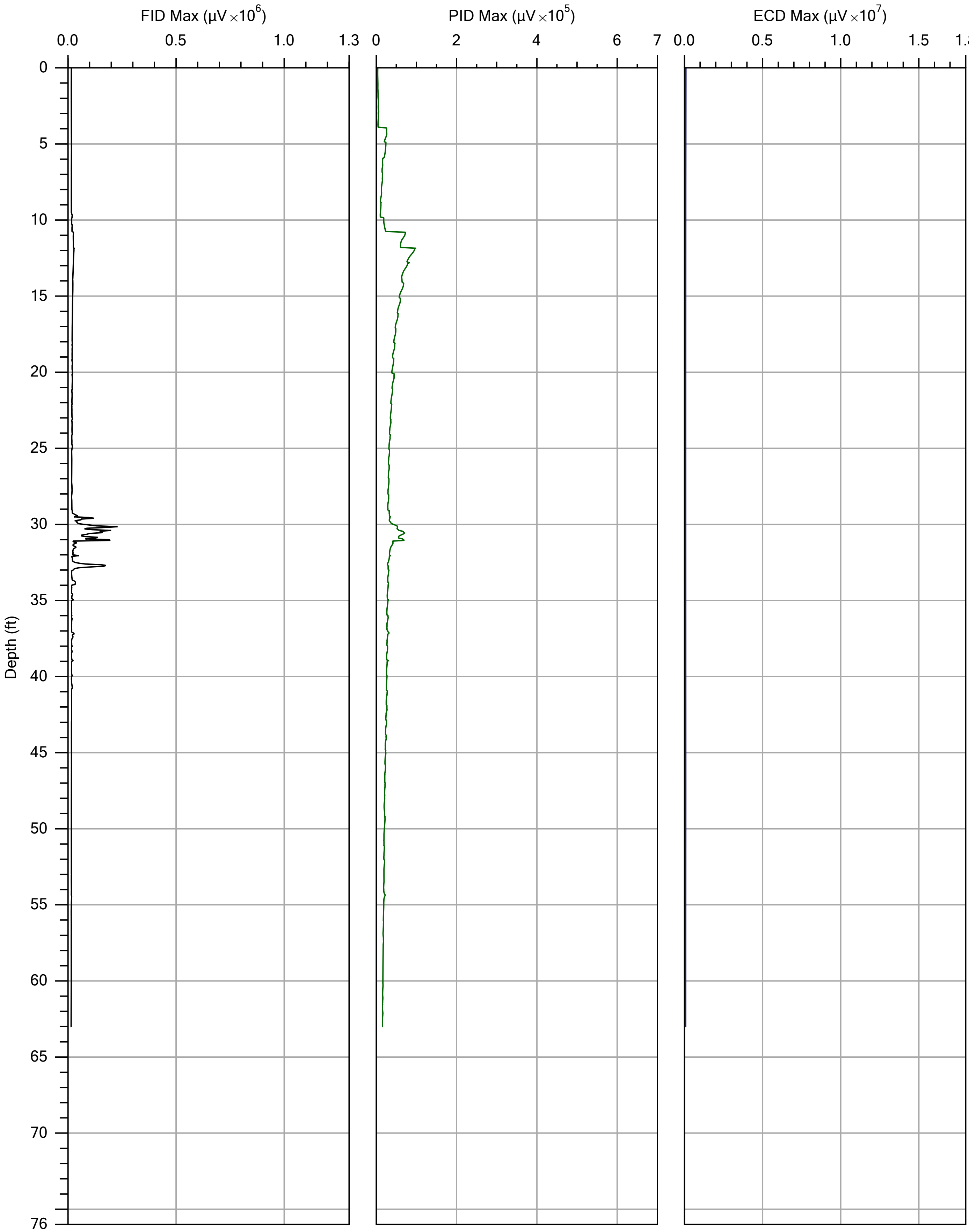

| Company: ERM | Operator: Albert Fonseca | File: MIP-C-06.MIP |
|---|---|---|
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Date: 1/4/2012 |
| | | Location: Crosby, TX |



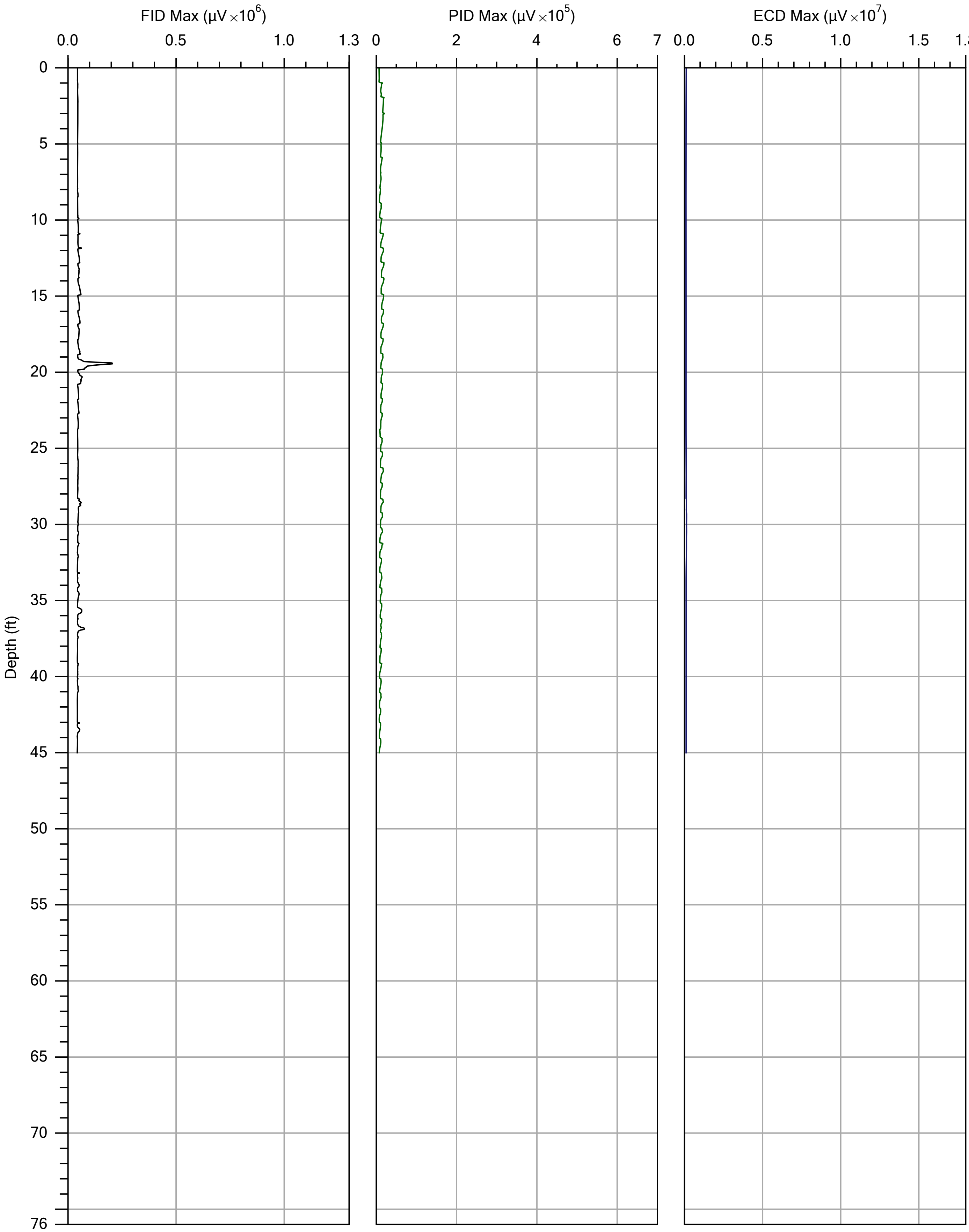

| | | |
|---|---|---|
| | | File: MIP-C-07.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 12/21/2011 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |



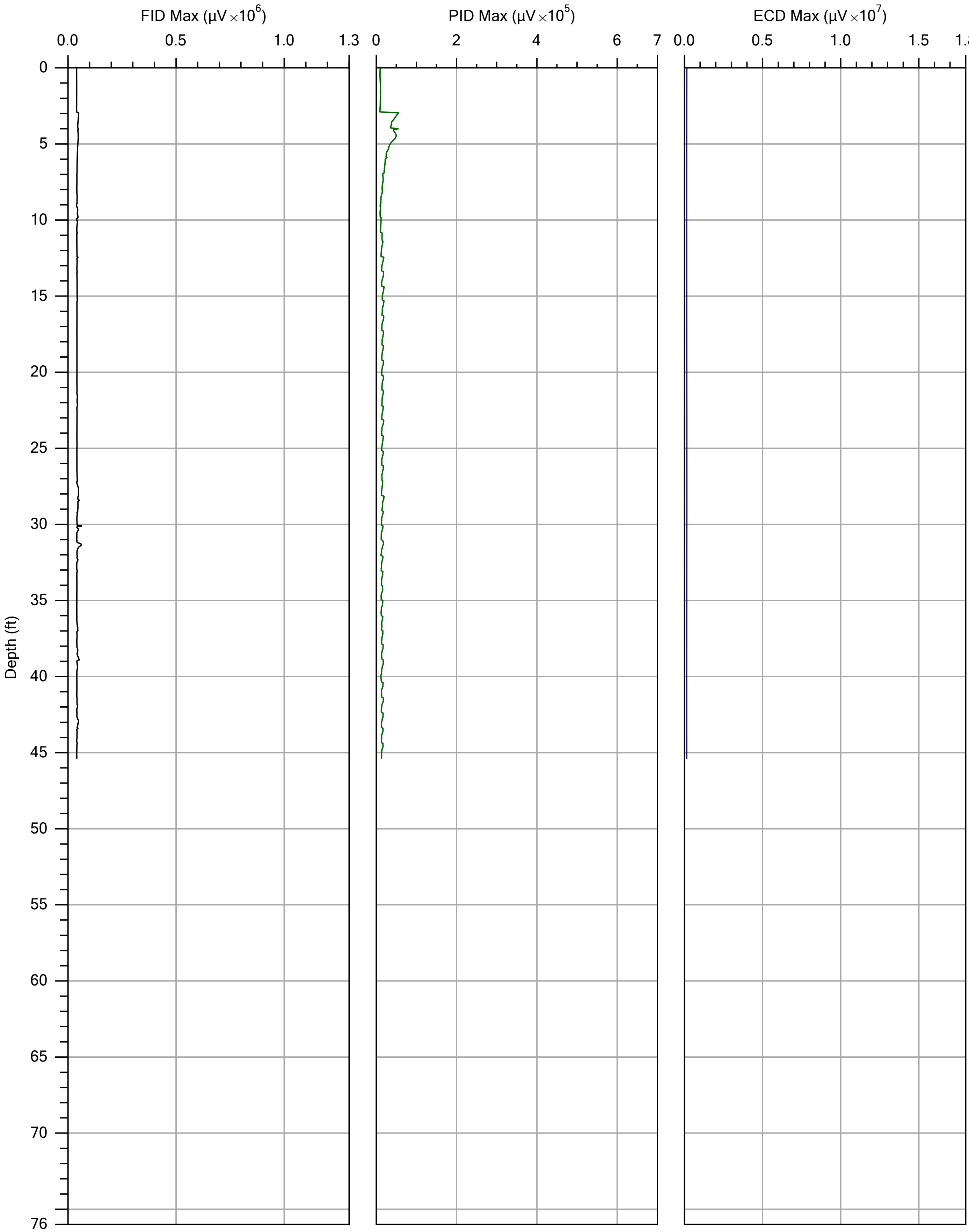

| | | |
|---|---|---|
| | | File: MIP-C-08.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/4/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |




| | | |
|---|---|---|
| | | File: MIP-C-09.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/3/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |




| | | |
|---|---|---|
| | | File: MIP-D-03.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/6/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |




| | | |
|---|---|---|
| | | File: MIP-E-05.MIP |
| Company: ERM | Operator: Albert Fonseca | Date: 1/5/2012 |
| Project ID: 04.1911-0063 | Client: Former French Ltd. Site | Location: Crosby, TX |

# Waterloo$^{APS}$ Logs

*Appendix D*

*April 2, 2014*
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000

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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client:** ERM

**Profile Location:** APS-01

| | Started | Completed |
|---|---|---|
| Dates: | 3/21/2013 | 3/22/2013 |

Location: Crosby, TX

SEI #:

Sampler(s): WJW

KPRO Box Serial # / Acquisition Laptop: 803/Rasc9

Troll Serial #: Hyd. 45358

Drilling Contractor: Best Drilling

Average Depth to Water: -3.20

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: #REF!

KPRO $N_2$ Pressure (set via P transducer): #REF!

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -47.50 | 3/21/13 16:24 | 800 | NC | 2651 | 1.14 | 6.38 | -96 | |
| -51.50 | 3/21/13 9:19 | 550 | -3.20 | 1254 | 3.24 | 6.40 | -56 | |
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**Client:** ERM

# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Profile Location:** APS-02

| | Started | Completed |
|---|---|---|
| Dates: | 3/21/2013 | 3/22/2013 |

Location: Crosby, TX

SEI #: 13-021

Sampler(s): VLD

KPRO Box Serial # / Acquisition Laptop: 801/Rasc7

Troll Serial #: 62752

Drilling Contractor: Best

Average Depth to Water: -5.35

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: 39.61

KPRO $N_2$ Pressure (set via P transducer): 69.53

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -39.10 | 3/21/13 15:30 | 700 | NC | 909 | 1.95 | 7.92 | -42 | collect dup. head slow to equilibrate |
| -43.00 | 3/22/13 9:09 | 800 | -4.50 | 953 | 5.25 | 7.70 | -60 | |
| -48.70 | 3/22/13 10:35 | 750 | -6.20 | 1916 | 0.50 | 6.30 | -100 | |

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**Client: ERM**

# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Profile Location:** APS-03

| | Started | Completed |
|---|---|---|
| Dates: | 3/18/2013 | 3/22/2013 |

Location: Crosby, TX

SEI #: 13-021

Sampler(s): VLD

KPRO Box Serial # / Acquisition Laptop: 801/Rasc7

Troll Serial #: 62751

Drilling Contractor: Best

Average Depth to Water: -7.68

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: 36.17

KPRO $N_2$ Pressure (set via P transducer): 69.62

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| **Depth** (ft) | **Date / Time** | **Volume Purged** (mL) | **Head** (ft) | **SC** (uS/cm) | **DO** (PPM) | **pH** | **ORP** (mV) | **COMMENTS** |
|---|---|---|---|---|---|---|---|---|
| -19.00 | 3/22/13 11:56 | 1000 | -5.15 | 1393 | 0.88 | 6.34 | 9 | |
| -24.00 | 3/18/13 11:10 | 700 | -7.20 | 1260 | 1.07 | 6.91 | -119 | |
| -27.70 | 3/18/13 11:40 | 800 | -8.30 | 1667 | 0.68 | 6.83 | -125 | |
| -44.00 | 3/18/13 13:04 | 800 | -7.60 | 595 | 2.20 | 7.53 | -75 | |
| -40.00 | 3/18/13 15:13 | 550 | -7.60 | 729 | 2.42 | 6.92 | -86 | |

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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client:** ERM

**Profile Location:** APS-04

| | Started | Completed |
|---|---|---|
| Dates: | 3/18/2013 | 3/19/2013 |

Location: Crosby, TX

SEI #: 13-021

Sampler(s): VLD

KPRO Box Serial # / Acquisition Laptop: 801/Rasc7

Troll Serial #: 62752

Drilling Contractor: Best

Average Depth to Water: -5.60

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: 34.66

KPRO $N_2$ Pressure (set via P transducer): 69.27

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -23.00 | 3/18/13 16:33 | 800 | -5.30 | 1593 | 1.21 | 6.83 | -133 | |
| -27.00 | 3/18/13 17:10 | 800 | -5.80 | 1976 | 1.21 | 6.85 | -118 | |
| -36.20 | 3/19/13 9:34 | 800 | -5.70 | 1230 | 1.76 | 6.93 | -68 | |
| -45.50 | 3/19/13 11:22 | 230 | NC | 543 | 6.94 | 7.26 | 39 | Sample not coming in, pull after 230 ml. |

N:\Projects\FLTG\French Limited\TI Waiver\Draft French Limited TI Waiver Report\Appendices\Appendix D - WaterlooAPS Logs\APS-04-ERM.xls

**Client: ERM** Started Completed

# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Profile Location:** APS-05

Dates: 3/21/2013

Location: Crosby, TX

SEI #:

Sampler(s): WJW

KPRO Box Serial # / Acquisition Laptop: 803/Rasc9

Troll Serial #: Hyd. 45358

Drilling Contractor: Best Drilling

Average Depth to Water: -3.84

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: #REF!

KPRO $N_2$ Pressure (set via P transducer): #REF!

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -37.00 | 3/21/13 10:49 | 600 | NC | 654 | 4.05 | 6.74 | -40 | |
| -48.70 | NC | NC | -5.92 | NC | NC | NC | NC | |
| -49.20 | NC | NC | -1.75 | NC | NC | NC | NC | |
| -51.90 | 3/21/13 13:44 | 350 | NC | 249 | 7.36 | 6.87 | 70 | |

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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client: ERM**

**Profile Location:** APS-06

| | Started | Completed |
|---|---|---|
| Dates: | 3/19/2013 | 3/20/2013 |

Location: Crosby, TX

SEI #: 13-021

Sampler(s): VLD

KPRO Box Serial # / Acquisition Laptop: 801/Rasc7

Troll Serial #: 62752

Drilling Contractor: Best

Average Depth to Water: -5.13

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: 34.99

KPRO $N_2$ Pressure (set via P transducer): 69.62

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -23.00 | 3/19/13 13:22 | 800 | -5.15 | 822 | 1.14 | 6.94 | -114 | |
| -28.00 | 3/19/13 14:01 | 700 | -5.10 | 1457 | 0.80 | 6.86 | -124 | |
| -38.80 | 3/19/13 17:03 | 700 | -5.15 | 899 | 9.40 | 7.93 | 34 | |
| -41.76 | 3/20/13 9:10 | 600 | NC | 1270 | 5.60 | 7.84 | -4 | head slow to equilibrate |
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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client:** **ERM**

**Profile Location:** APS-07

| | Started | Completed |
|---|---|---|
| Dates: | 3/18/2013 | 3/19/2013 |

Location: Crosby, TX

SEI #:

Sampler(s): WJW

KPRO Box Serial # / Acquisition Laptop: 803/Rasc9

Troll Serial #: Hyd. 45358

Drilling Contractor: Best Drilling

Average Depth to Water: -3.30

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: #REF!

KPRO $N_2$ Pressure (set via P transducer): #REF!

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -23.40 | 3/18/13 11:39 | 1000 | -4.30 | 1485 | 0.97 | 6.33 | 1 | |
| -27.00 | 3/18/13 12:44 | 1200 | -4.30 | 2188 | 0.46 | 6.20 | -74 | |
| -32.20 | 3/18/13 13:55 | 600 | NC | 2066 | 2.18 | 6.49 | -38 | |
| -40.80 | 3/18/13 15:37 | 500 | NC | 586 | 7.35 | 7.74 | 51 | |
| -45.50 | 3/18/13 17:13 | 500 | -1.90 | 343 | 6.07 | 6.89 | 59 | |
| -52.70 | 3/19/13 10:10 | 500 | -2.70 | 198 | 8.77 | 7.05 | 116 | |
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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client:** ERM

**Profile Location:** APS-08

Started Completed

Dates: 3/19/2013

Location: Crosby, TX

SEI #:

Sampler(s): WJW

KPRO Box Serial # / Acquisition Laptop: 803/Rasc9

Troll Serial #: Hyd. 45358

Drilling Contractor: Best Drilling

Average Depth to Water: -2.95

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: #REF!

KPRO $N_2$ Pressure (set via P transducer): #REF!

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -20.10 | 3/19/13 12:12 | 700 | -2.75 | 803 | 0.03 | 6.83 | -161 | |
| -24.60 | 3/19/13 13:16 | 800 | -3.15 | 1602 | 0.03 | 6.54 | -142 | |

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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client:** **ERM**

**Profile Location:** APS-09

| | Started | Completed |
|---|---|---|
| Dates: | 3/20/2013 | 3/21/2013 |

Location: Crosby, TX

SEI #: 13-021

Sampler(s): VLD

KPRO Box Serial # / Acquisition Laptop: 801/Rasc7

Troll Serial #: 62752

Drilling Contractor: Best

Average Depth to Water: -3.77

Gas Drive or Peri Pump: Peri

Atmospheric Pressure: 35.2

KPRO $N_2$ Pressure (set via P transducer): 68.7

Gas Drive Pump $N_2$ Pressure: NA

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -17.00 | 3/20/13 15:16 | 700 | -3.75 | 1039 | 1.52 | 7.15 | -46 | |
| -22.00 | 3/20/13 15:46 | 800 | -3.65 | 1467 | 1.18 | 6.96 | -82 | |
| -26.34 | 3/20/13 16:14 | 700 | -3.70 | 1379 | 1.07 | 7.14 | -122 | |
| -43.88 | 3/21/13 10:34 | 850 | -3.96 | 1359 | 1.08 | 7.00 | -26 | |
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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client:** ERM

**Profile Location:** APS-10

| | | |
|---|---|---|
| Dates: Started 3/20/2013, Completed 3/20/2013 | KPRO Box Serial # / Acquisition Laptop: 801/Rasc7 | Gas Drive or Peri Pump: Peri |
| Location: Crosby, TX | Troll Serial #: 62752 | Atmospheric Pressure: 35.25 |
| SEI #: 13-021 | Drilling Contractor: Best | KPRO $N_2$ Pressure (set via P transducer): 69.21 |
| Sampler(s): VLD | Average Depth to Water: -1.97 | Gas Drive Pump $N_2$ Pressure: NA |

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -21.00 | 3/20/13 10:18 | 700 | -2.00 | 523 | 3.54 | 7.00 | -99 | |
| -25.20 | 3/20/13 10:57 | 750 | -1.94 | 1091 | 0.97 | 7.17 | -134 | |
| -45.20 | 3/20/13 13:35 | 500 | nc | 475 | 3.90 | 7.66 | -78 | Head slow to equilibrate |
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# GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

**Client:** **ERM**

**Profile Location:** APS-11

| | | | |
|---|---|---|---|
| Dates: (Started / Completed) | 3/20/2013 | KPRO Box Serial # / Acquisition Laptop: | 803/Rasc9 |
| Location: | Crosby, TX | Troll Serial #: | Hyd. 45358 |
| SEI #: | | Drilling Contractor: | Best Drilling |
| Sampler(s): | WJW | Average Depth to Water: | -1.95 |

| | |
|---|---|
| Gas Drive or Peri Pump: | Peri |
| Atmospheric Pressure: | 0 |
| KPRO $N_2$ Pressure (set via P transducer): | 0 |
| Gas Drive Pump $N_2$ Pressure: | NA |

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -21.00 | 3/20/13 8:42 | 1000 | -1.95 | 895 | 0.76 | 6.43 | -92 | |
| -26.20 | 3/20/13 9:06 | 1000 | -1.95 | 773 | 0.75 | 6.23 | -95 | |
| -36.60 | 3/20/13 10:08 | 500 | NC | 674 | 3.82 | 6.89 | -75 | |
| -50.60 | 3/20/13 11:12 | 500 | NC | 905 | 6.69 | 6.97 | -19 | |

# GROUNDWATER PROFILE LOG

**Client:** **ERM**

STONE ENVIRONMENTAL INC

**Profile Location:** APS-12

| | | | |
|---|---|---|---|
| Dates: (Started / Completed) | 3/20/2013 | Gas Drive or Peri Pump: | Peri |
| KPRO Box Serial # / Acquisition Laptop: | 803/Rasc9 | Atmospheric Pressure: | 0 |
| Location: | Crosby, TX | KPRO $N_2$ Pressure (set via P transducer): | 0 |
| Troll Serial #: | Hyd. 45358 | Gas Drive Pump $N_2$ Pressure: | NA |
| SEI #: | | Drilling Contractor: | Best Drilling |
| Sampler(s): | WJW | Average Depth to Water: | -2.39 |

## PHYSICOCHEMICAL PARAMETERS

| Depth (ft) | Date / Time | Volume Purged (mL) | Head (ft) | SC (uS/cm) | DO (PPM) | pH | ORP (mV) | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| -22.00 | 3/20/13 12:19 | 1200 | -2.30 | 818 | 0.63 | 6.24 | -2 | |
| -26.90 | 3/20/13 12:54 | 1000 | -2.40 | 886 | 0.67 | 6.43 | -72 | |
| -34.30 | 3/20/13 14:36 | 500 | -2.45 | 678 | 5.95 | 7.13 | -13 | |
| -39.10 | 3/20/13 15:48 | 450 | NC | 1490 | 4.36 | 6.62 | 20 | |
| -44.50 | 3/20/13 16:21 | 900 | -2.42 | 1255 | 0.87 | 6.98 | 8 | |

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# CPT/MIP/Waterloo$^{APS}$ Combined Logs

*Appendix E*

*April 2, 2014*
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-A-01/APS-01



**Client:** French Limited

**Project Name:** Subsurface Investigation

**Project Number:** 0184582

**Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 12/20/2011

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/22/2013

**GROUND SURFACE ELEVATION:** 13.6 ft above MSL

**NOTES:** APS location is within 5 feet of the CPT/MIP location.

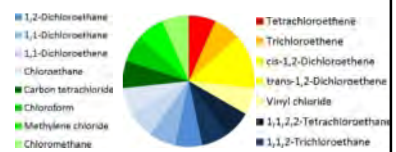
**ACRONYM LEGEND**

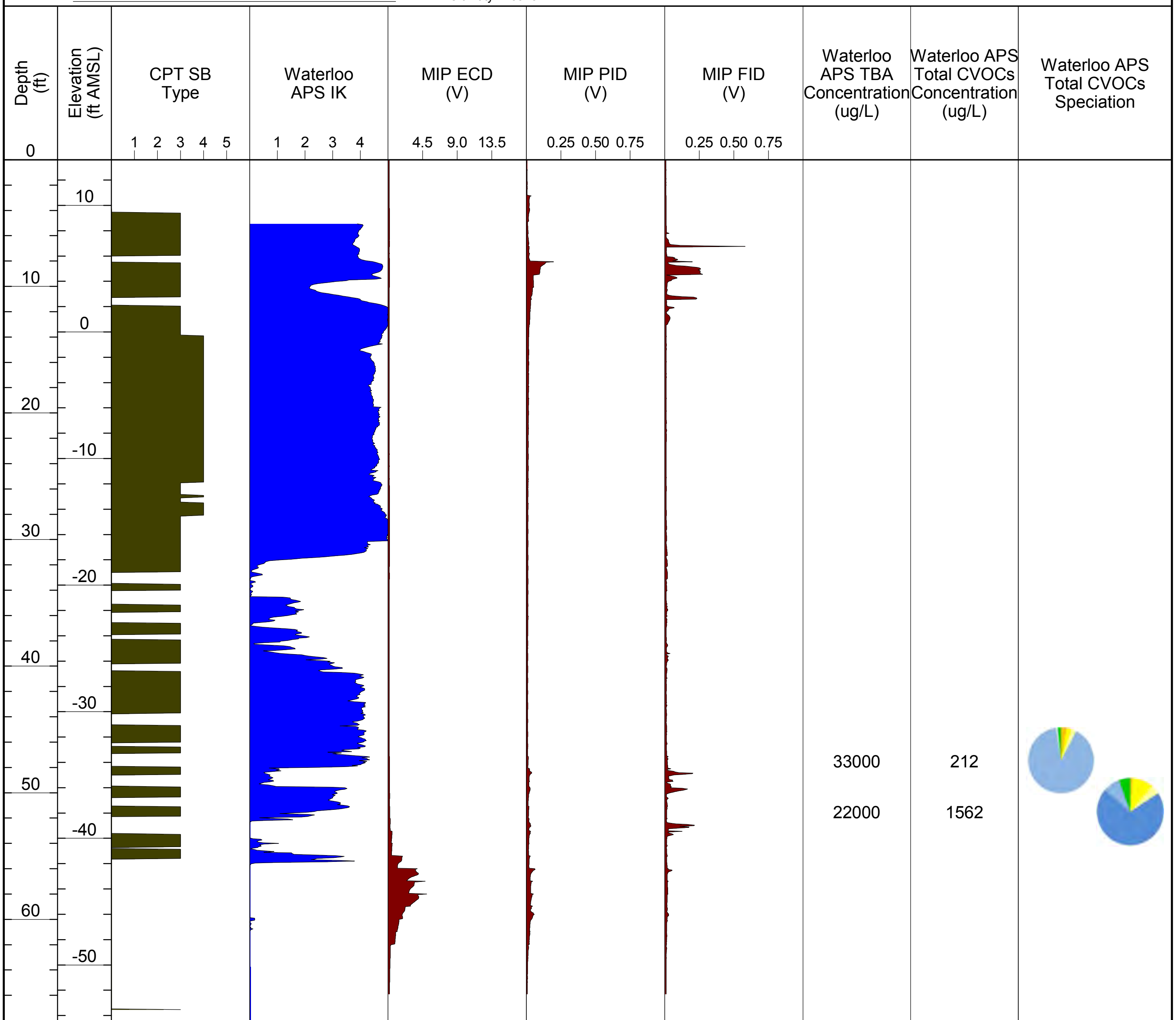
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**

0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 68.50 ft
Bottom of CPT @ 67.32 ft
Bottom of MIP @ 66.75 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-A-02A/APS-02



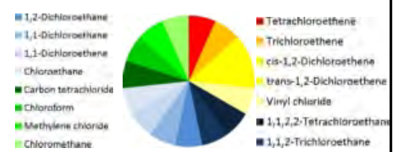
**Client:** French Limited
**Project Name:** Subsurface Investigation
**Project Number:** 0184582
**Project Location:** Crosby, TX

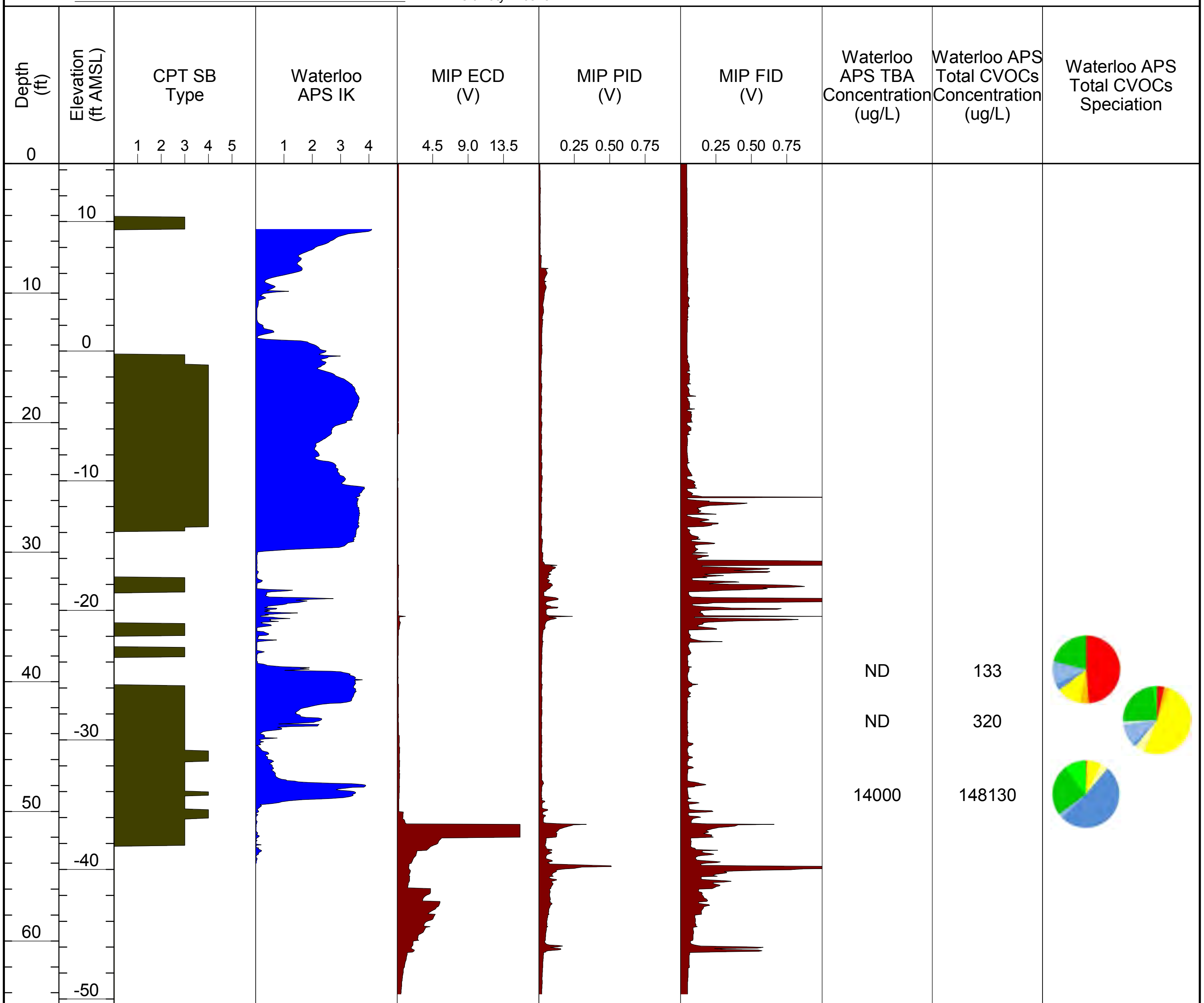
**CPT/MIP CONTRACTOR:** Fugro
**DATE CPT/MIP COMPLETED:** 1/10/2012
**APS CONTRACTOR:** Stone Environmental, Inc.
**DATE APS COMPLETED:** 3/22/2013
**GROUND SURFACE ELEVATION:** 14.48 ft above MSL
**NOTES:** APS location is within 5 feet of the CPT/MIP location.

**ACRONYM LEGEND**
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**
0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 54.00 ft
Bottom of CPT @ 65.42 ft
Bottom of MIP @ 64.85 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-A-03/APS-03



**Client:** French Limited

**Project Name:** Subsurface Investigation

**Project Number:** 0184582

**Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 12/19/2011

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/22/2013

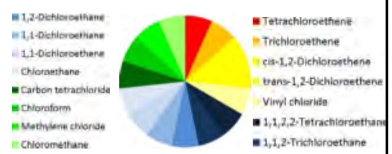
**GROUND SURFACE ELEVATION:** 14.26 ft above MSL

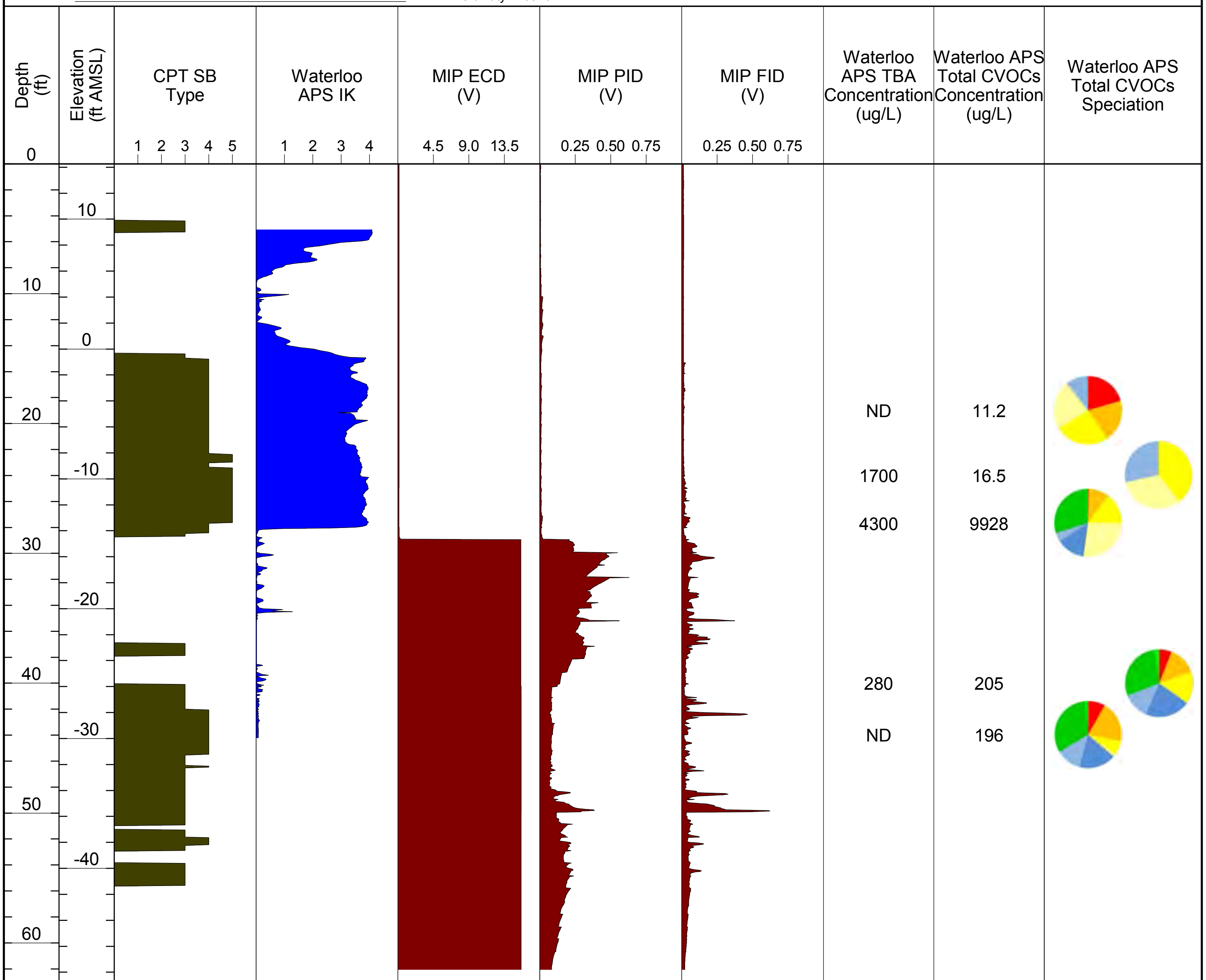
**NOTES:** APS location is within 5 feet of the CPT/MIP location.

**ACRONYM LEGEND**
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**
0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 44.20 ft
Bottom of CPT @ 63.45 ft
Bottom of MIP @ 62.80 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-A-06/APS-04



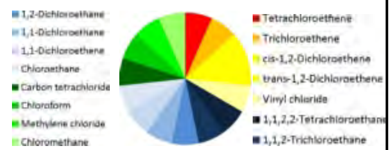
**Client:** French Limited
**Project Name:** Subsurface Investigation
**Project Number:** 0184582
**Project Location:** Crosby, TX

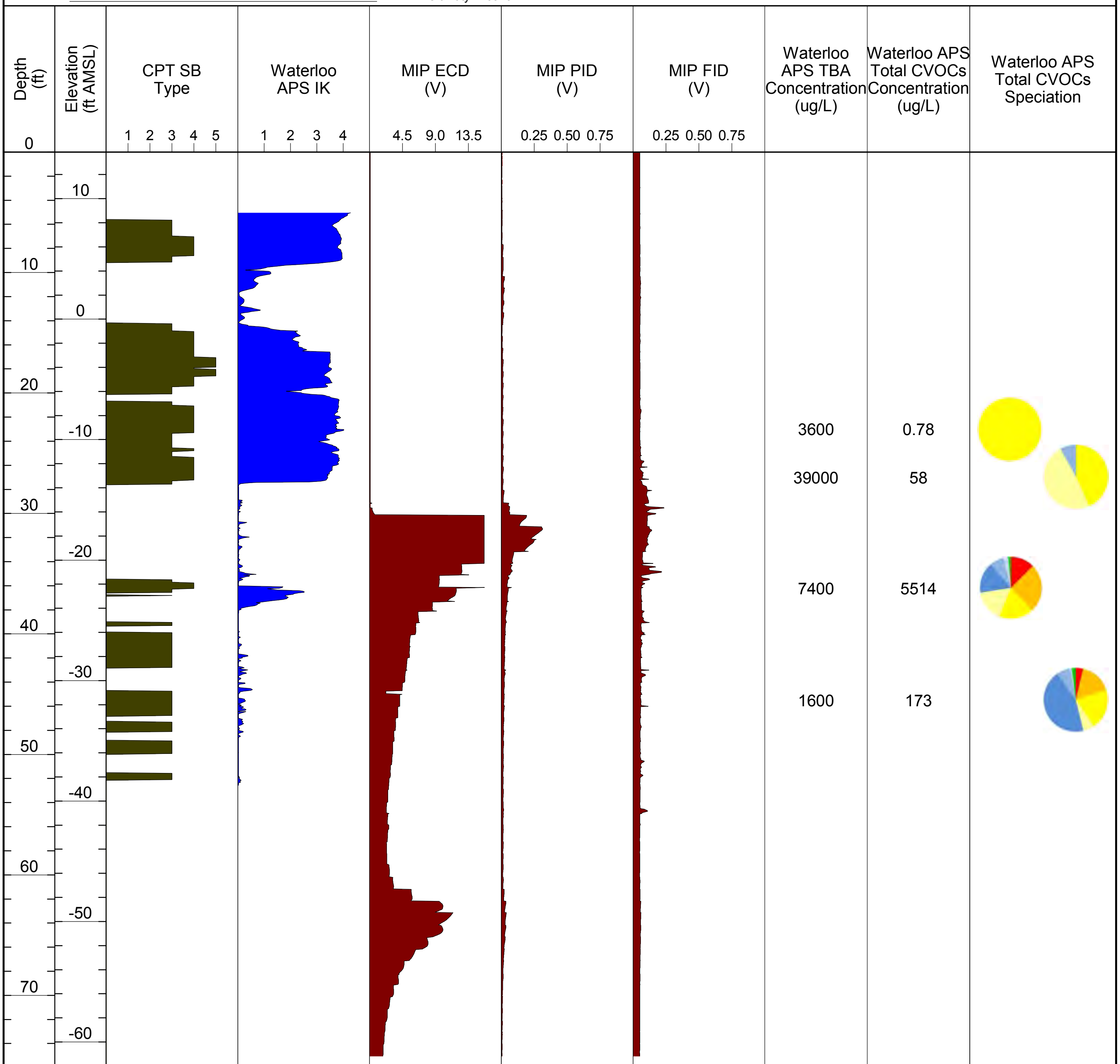
**CPT/MIP CONTRACTOR:** Fugro
**DATE CPT/MIP COMPLETED:** 1/5/2012
**APS CONTRACTOR:** Stone Environmental, Inc.
**DATE APS COMPLETED:** 3/19/2013
**GROUND SURFACE ELEVATION:** 13.87 ft above MSL
**NOTES:** APS location is within 5 feet of the CPT/MIP location.

**ACRONYM LEGEND**
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**
0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 52.55 ft
Bottom of CPT @ 76.44 ft
Bottom of MIP @ 75.80 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-A-07/APS-05



**Client:** French Limited

**Project Name:** Subsurface Investigation

**Project Number:** 0184582

**Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 12/19/2011

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/21/2013

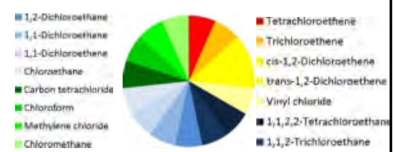
**GROUND SURFACE ELEVATION:** 13.64 ft above MSL

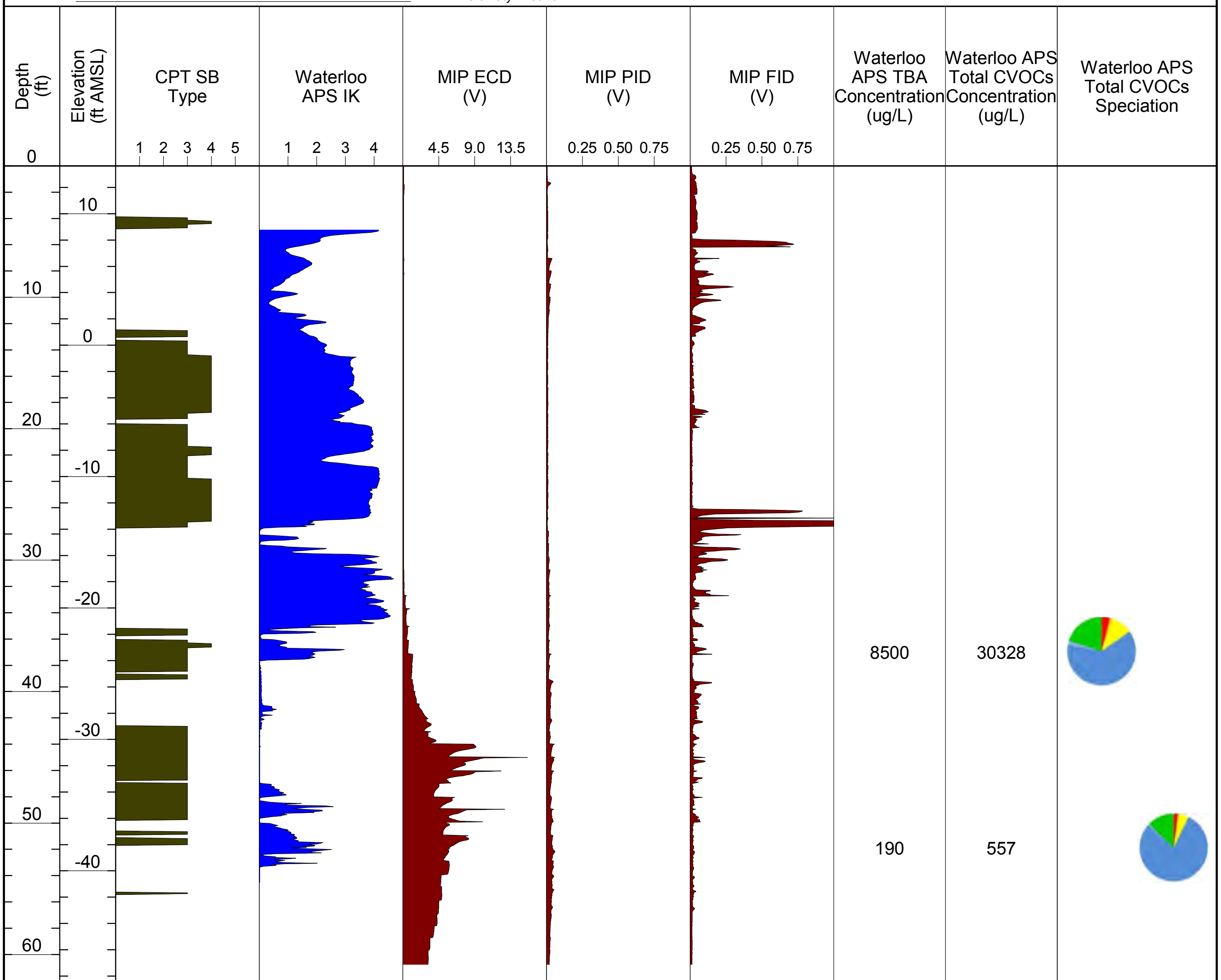
**NOTES:** APS location is within 5 feet of the CPT/MIP location

**ACRONYM LEGEND**
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**
0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 54.50 ft
Bottom of CPT @ 62.53 ft
Bottom of MIP @ 61.50 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-B-03/APS-06



**Client:** French Limited

**Project Name:** Subsurface Investigation

**Project Number:** 0184582

**Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 1/6/2012

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/20/2013

**GROUND SURFACE ELEVATION:** 12.52 ft above MSL

**NOTES:** APS location is within 5 feet of the CPT/MIP location.

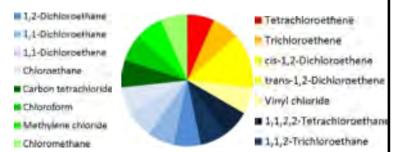
**ACRONYM LEGEND**

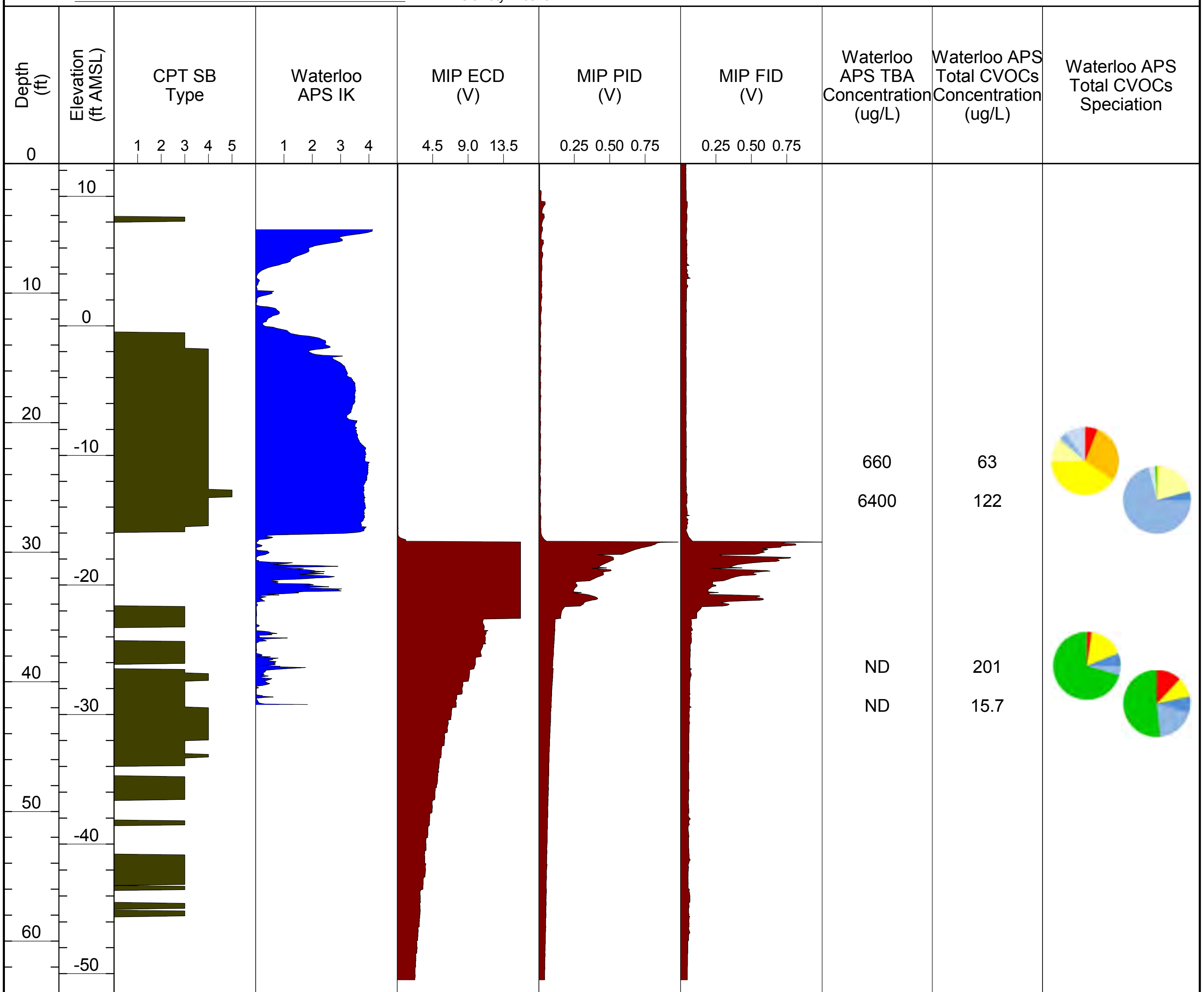
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**

0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 41.76 ft
Bottom of CPT @ 64.50 ft
Bottom of MIP @ 63.75 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-B-04/APS-07



**Client:** French Limited

**Project Name:** Subsurface Investigation

**Project Number:** 0184582

**Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 1/4/2012

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/19/2013

**GROUND SURFACE ELEVATION:** 11.78 ft above MSL

**NOTES:** APS location is within 5 feet of the CPT/MIP location.

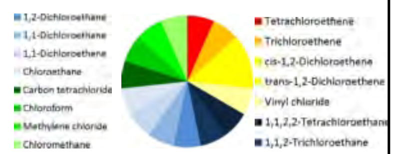
**ACRONYM LEGEND**

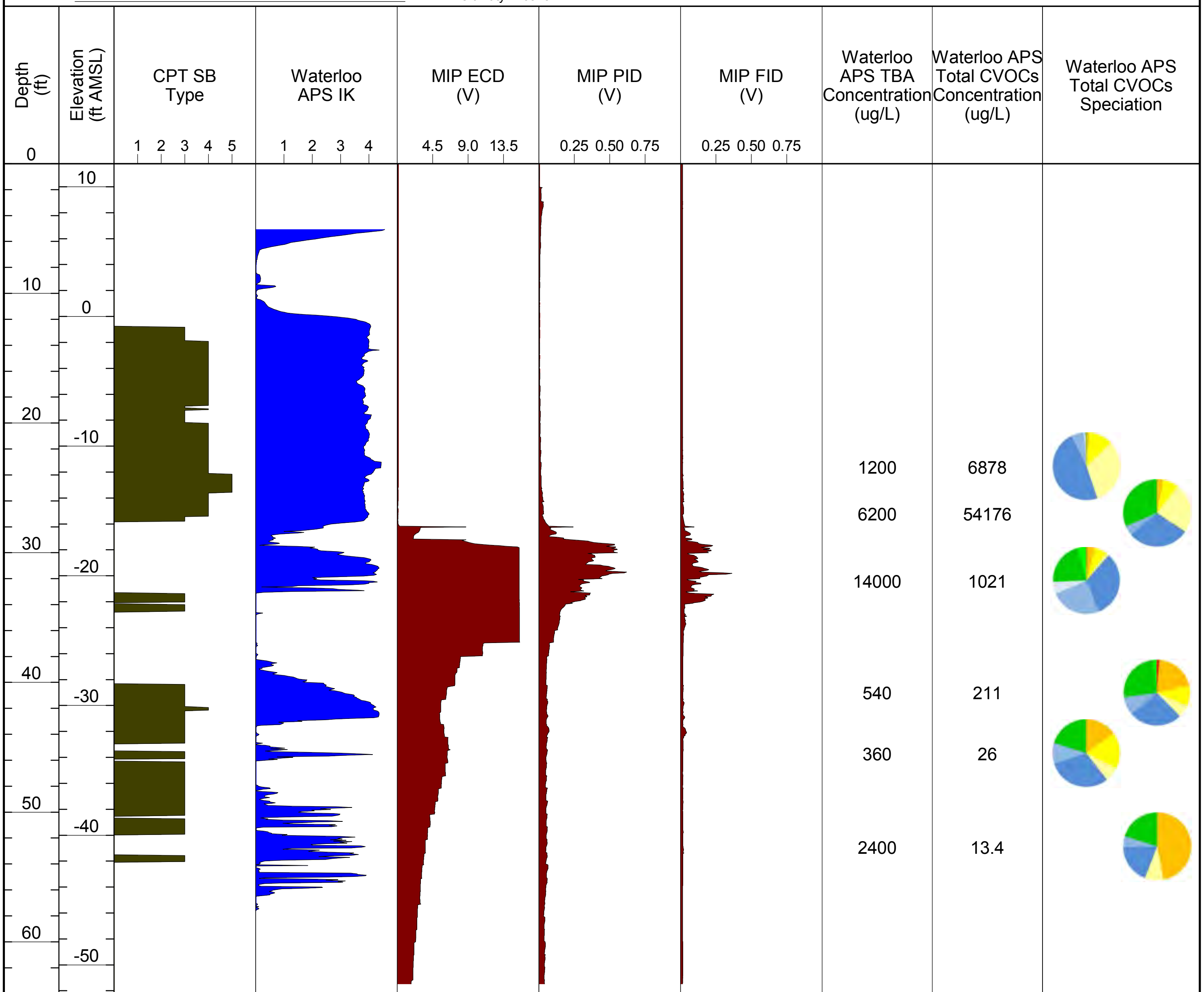
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**

0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 57.60 ft
Bottom of CPT @ 64.37 ft
Bottom of MIP @ 64.00 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-B-06/APS-08



**Client:** French Limited

**Project Name:** Subsurface Investigation

**Project Number:** 0184582

**Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 1/3/2012

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/19/2013

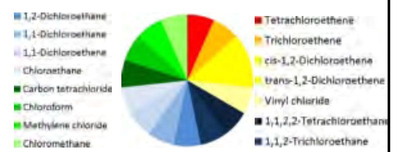
**GROUND SURFACE ELEVATION:** 11.44 ft above MSL

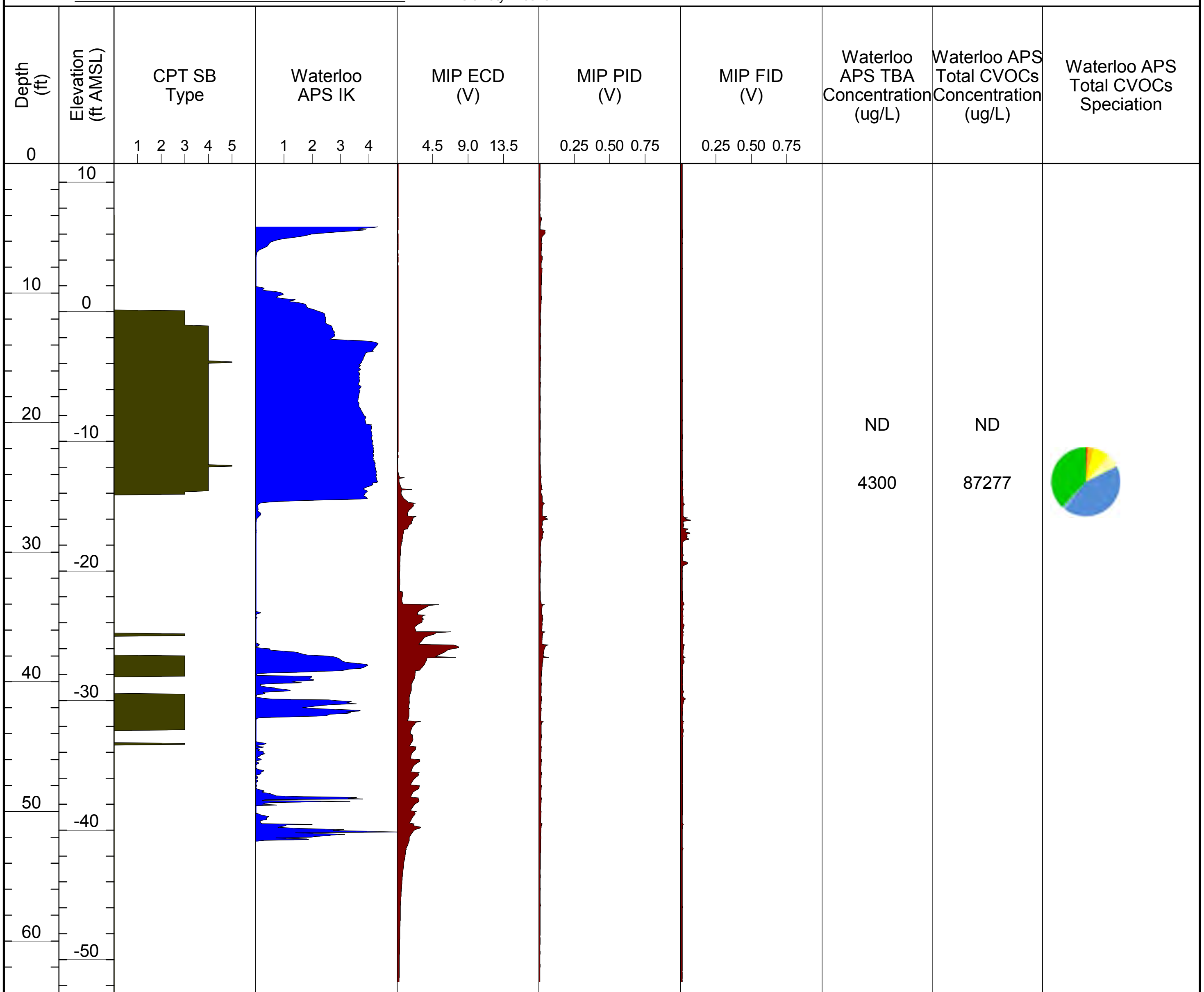
**NOTES:** APS location is within 5 feet of the CPT/MIP location

**ACRONYM LEGEND**
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**
0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 52.30 ft
Bottom of CPT @ 64.50 ft
Bottom of MIP @ 63.90 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-B-07/APS-09



**Client:** French Limited **Project Name:** Subsurface Investigation

**Project Number:** 0184582 **Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 1/4/2012

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/21/2013

**GROUND SURFACE ELEVATION:** 11.72 ft above MSL

**NOTES:** APS location is within 5 feet of the CPT/MIP location.

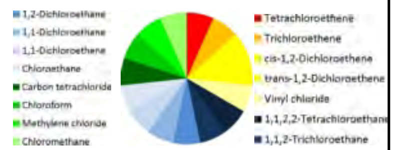
**ACRONYM LEGEND**

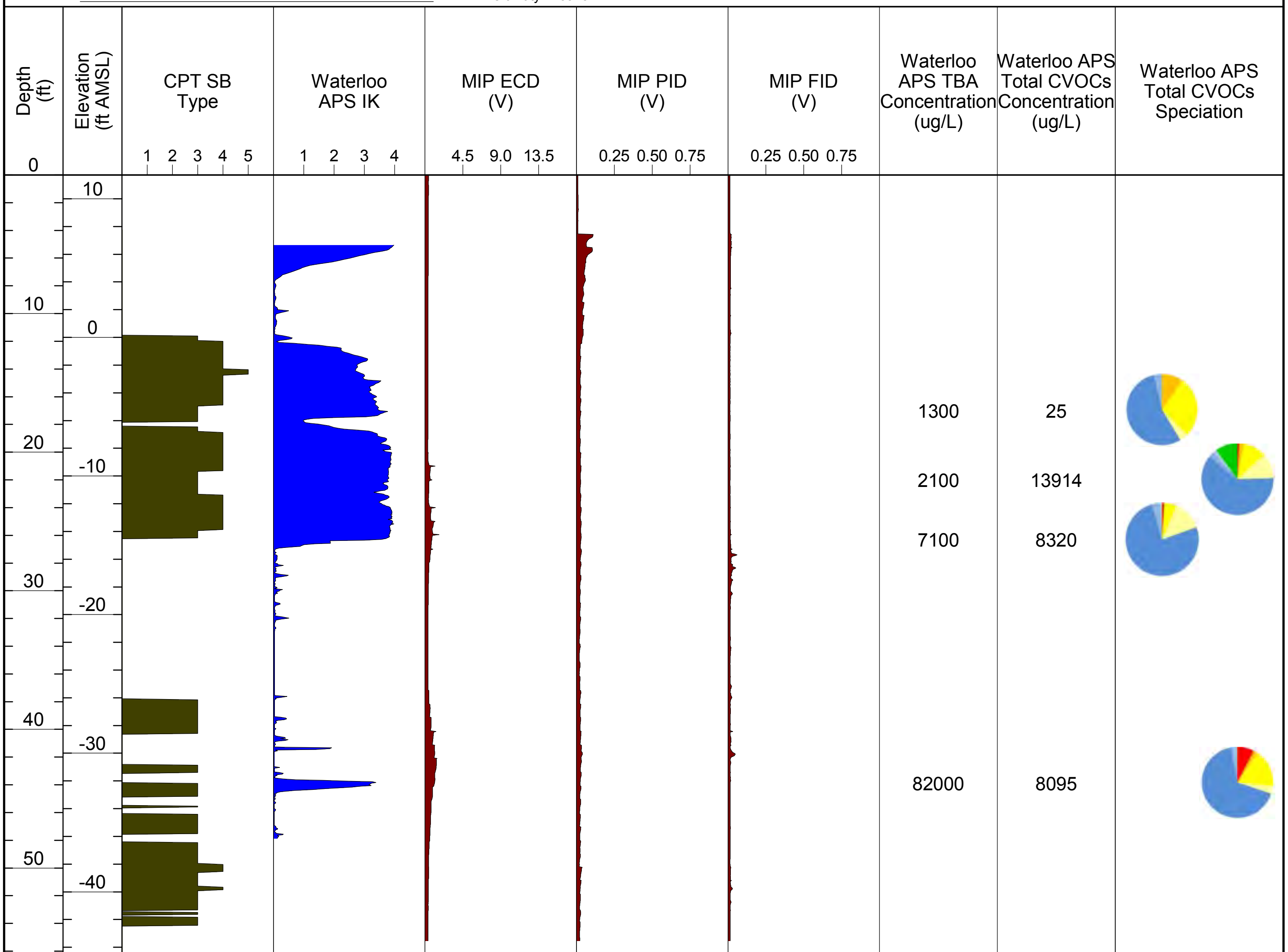
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**

0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 47.86 ft
Bottom of CPT @ 56.50 ft
Bottom of MIP @ 56.00 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-C-05/APS-10



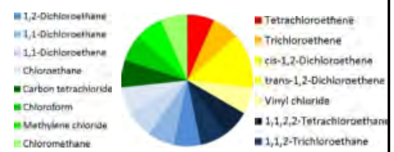
**Client:** French Limited
**Project Name:** Subsurface Investigation
**Project Number:** 0184582
**Project Location:** Crosby, TX

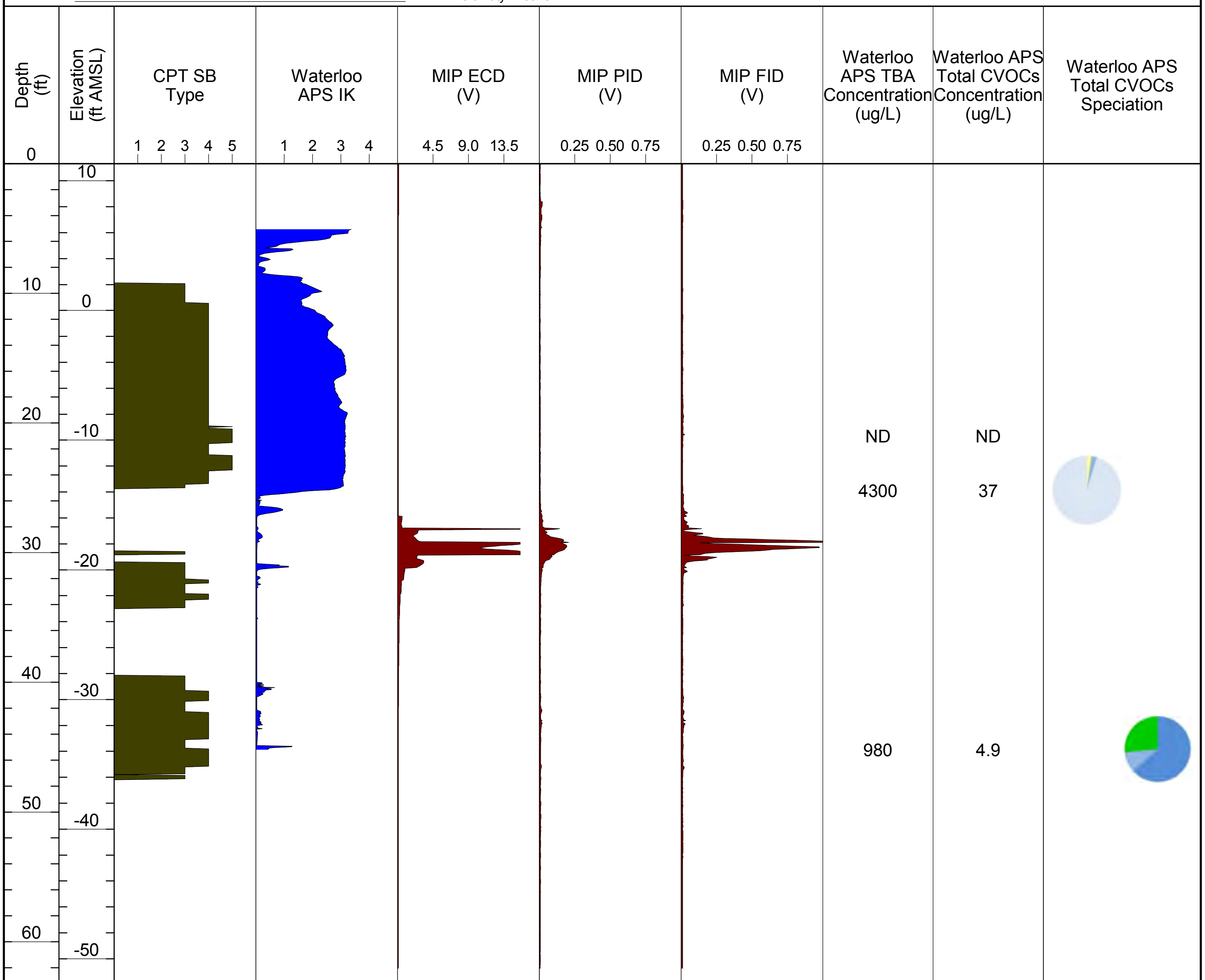
**CPT/MIP CONTRACTOR:** Fugro
**DATE CPT/MIP COMPLETED:** 12/21/2011
**APS CONTRACTOR:** Stone Environmental, Inc.
**DATE APS COMPLETED:** 3/20/2013
**GROUND SURFACE ELEVATION:** 11.32 ft above MSL
**NOTES:** APS location is within 5 feet of the CPT/MIP location

**ACRONYM LEGEND**
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**
0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 45.20 ft
Bottom of CPT @ 63.45 ft
Bottom of MIP @ 62.80 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-C-06/APS-11



**Client:** French Limited | **Project Name:** Subsurface Investigation

**Project Number:** 0184582 | **Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 1/4/2012

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/20/2013

**GROUND SURFACE ELEVATION:** 11.62 ft above MSL

**NOTES:** APS location is within 5 feet of the CPT/MIP location.

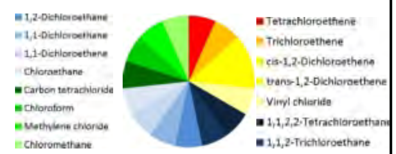
**ACRONYM LEGEND**

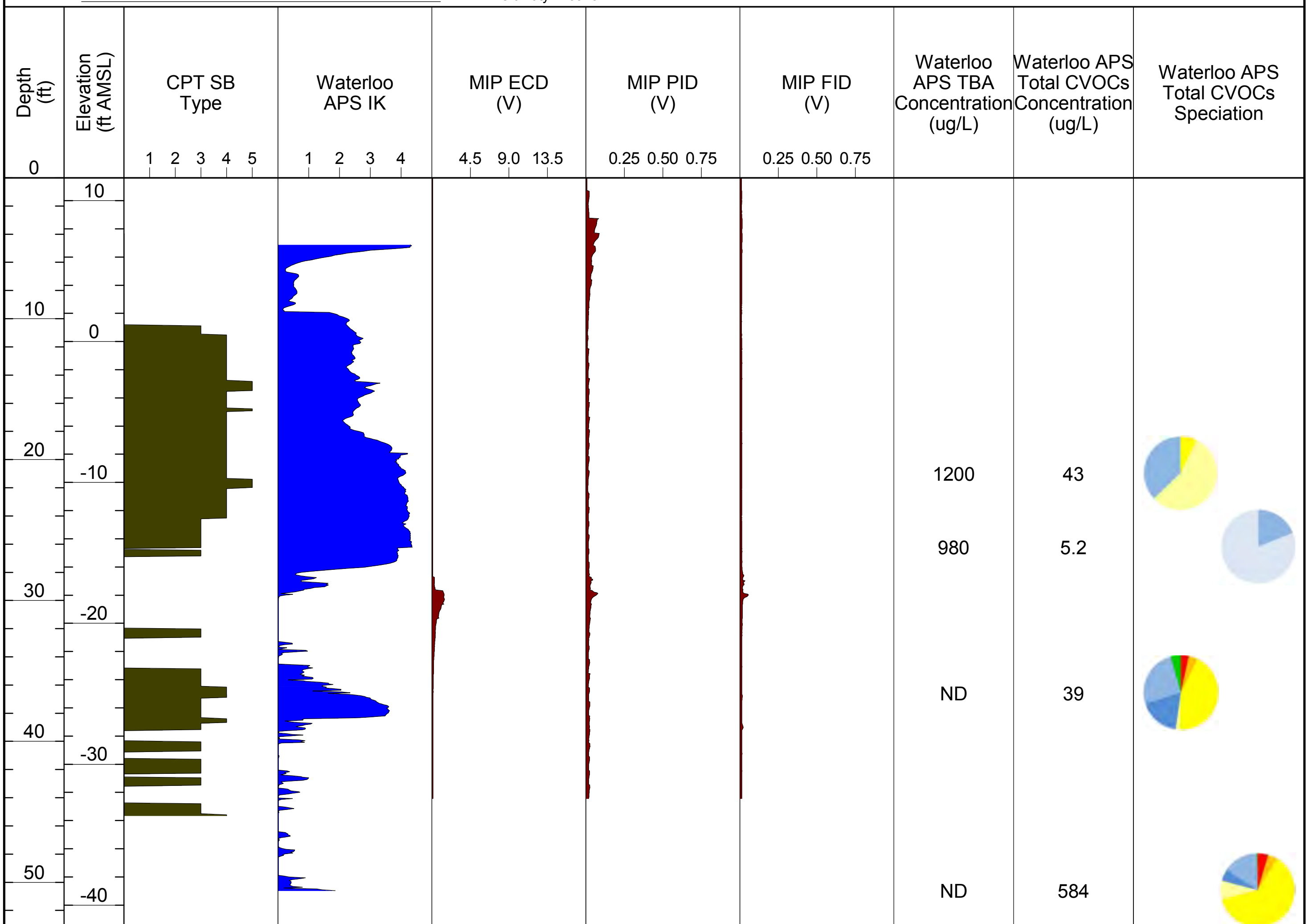
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**

0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 50.60 ft
Bottom of CPT @ 45.47 ft
Bottom of MIP @ 44.80 ft

ERM
99 East River Drive, 3rd floor
East Hartford, CT 06108
Telephone: (860) 466-8500
Fax: (860) 466-8501

# CPT/MIP-C-07/APS-12



**Client:** French Limited **Project Name:** Subsurface Investigation

**Project Number:** 0184582 **Project Location:** Crosby, TX

**CPT/MIP CONTRACTOR:** Fugro

**DATE CPT/MIP COMPLETED:** 12/21/2011

**APS CONTRACTOR:** Stone Environmental, Inc.

**DATE APS COMPLETED:** 3/20/2013

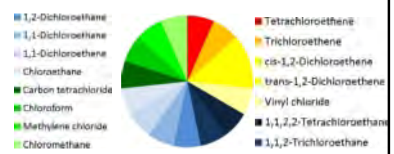
**GROUND SURFACE ELEVATION:** 11.85 ft above MSL

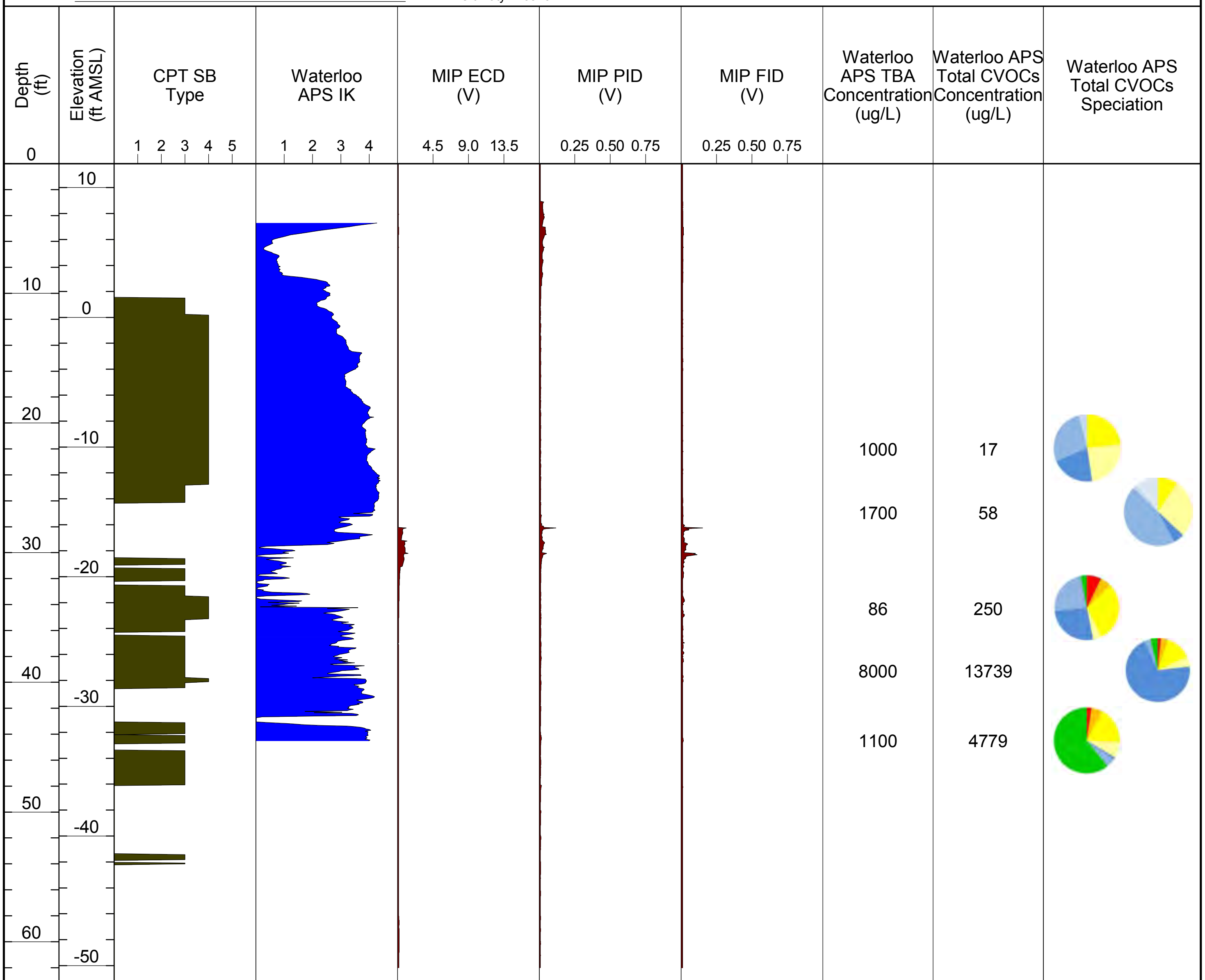
**NOTES:** APS location is within 5 feet of the CPT/MIP location.

**ACRONYM LEGEND**
APS = Waterloo Advanced Profiling System
CPT = Cone Penetration Test
CVOC = Chlorinated Volatile Organic Compounds
ECD = Electron Capture Detector
FID = Flame Ionization Probe
MIP = Membrane Interface Probe
MSL = Mean Sea Level
NS = Not Sampled
PID = Photo Ionization Detector
TBA = Tert Butyl Alcohol

**CPT SOIL BEHAVIOR TYPE LEGEND**
0 = Silty Clay to Clayey Silt, Sensitive Fine Grained, or Organic Material
3 = Silty Sand to Clayey Sand
4 = Sand
5 = Gravelly Sand

**CVOC SPECIATION LEGEND**




Bottom of APS Boring @ 44.50 ft
Bottom of CPT @ 63.45 ft
Bottom of MIP @ 62.75 ft

# Restoration Analysis Supporting Information

*Appendix F*

*April 2, 2014*

*Project No. 0234672*

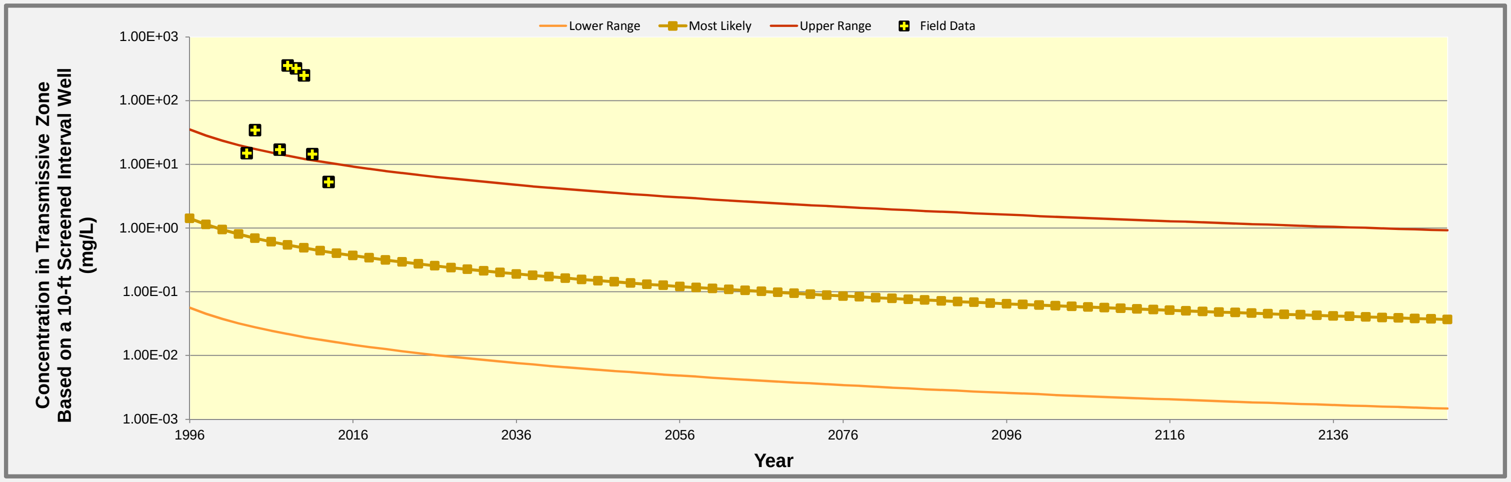
**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000

Matrix Diffusion Toolbox
Central Plume Area INT UNIT
1,2-DCA

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Time (yr)** | 2116 | 2118 | 2120 | 2122 | 2124 | 2126 | 2128 | 2130 | 2132 | 2134 | 2136 | 2138 | 2140 | 2142 | 2144 | 2146 | 2148 | 2150 |
| **Mass Discharge (g/day)** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Mass (kg)** | 1.43 | 1.42 | 1.41 | 1.40 | 1.39 | 1.38 | 1.37 | 1.36 | 1.35 | 1.34 | 1.33 | 1.32 | 1.32 | 1.31 | 1.30 | 1.29 | 1.28 | 1.28 |
| **Concentration (mg/L)** | 0.0513 | 0.0502 | 0.0492 | 0.0481 | 0.0471 | 0.0462 | 0.0453 | 0.0444 | 0.0435 | 0.0427 | 0.0419 | 0.0411 | 0.0403 | 0.0396 | 0.0389 | 0.0382 | 0.0375 | 0.0369 |
| **Plume Magnitude** | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 | Mag 3 |

Note: Negative mass discharge values represent diffusion into the low-k zone from the transmissive zone. Positive values represent diffusion from the low-k zone into the transmissive zone.

*What's up with the gap?*




Log | Linear

Re-Plot Graph from Year 1995 to Year 2100
(format: yyyy) (format: yyyy)

Update Graph

Restore Original Interval | Restore Original Graph

**Next Step: Save Data**

See Mass Discharge Results | See Mass Results

Return to SRM Data Input | Export/Print Data Table

Run Advanced Uncertainty Analysis

Return to Main Screen | *HELP*

Matrix Diffusion Toolbox
Central Plume Area INT UNIT
1,2-DCA

## SRM Data Input Screen

*Matrix Diffusion Toolkit* *Version 1.2*

Site Location and ID: FLTG CENTRAL Plume - INT UNIT

**DATA INPUT INSTRUCTIONS**

Enter value directly.

Value calculated by Toolkit. Do not enter data.

**1. SYSTEM UNITS**

(●) SI Units ○ English Units

**2. ANALYSIS TYPE**

○ Source Zone Analysis (●) Plume Analysis ○ PRB Analysis ?

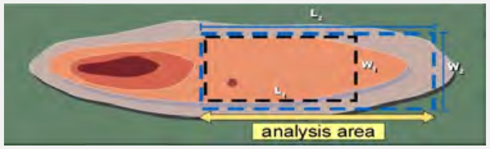
**3. HYDROGEOLOGY**

| | | | |
|---|---|---|---|
| Low-k Zone Description | | INT | User Input |
| Low-k Zone Total Porosity | $\Phi$ | 0.47 | (-) |
| Transmissive Zone Darcy Velocity | $V_d$ | 3.17E-06 | (cm/sec) Calculate Vd ? |

**4. TRANSPORT - Low-k Zone**

| | | | |
|---|---|---|---|
| Key Constituent | | 12-DCA | 12-DCA |
| Molecular Diffusion Coefficient in Free Water | $D_o$ | 9.90E-10 | (m2/sec) |
| Apparent Tortuosity Factor Exponent | $p$ | 1.10 | (-) |
| Retardation Factor | $R$ | 3.30 | (-) Calculate R ? |

**5. PLUME CHARACTERISTICS**



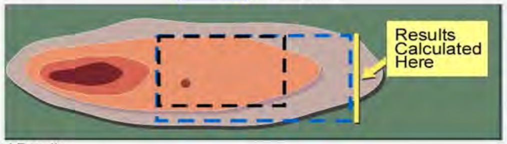

| | | | |
|---|---|---|---|
| High Concentration Zone (Black Box in Picture) | | | |
| Approximate Length (Length of Black Box) | $L_1$ | 6.70E+01 | (m) ? |
| Approximate Width (Width of Black Box) | $W_1$ | 1.60E+01 | (m) |
| Highest Historical Concentration in Black Box | | 3.58E+02 | (mg/L) |
| Concentration of Contour Line in Black Box | | 5.00E-01 | (mg/L) |
| Representative Concentration (OK to Override) | $C_{s1}$ | 1.20E+01 | (mg/L) Restore |
| Next Highest Concentration Zone (Blue Box in Picture) | | | |
| Approximate Length (Length of Blue Box) | $L_2$ | 1.00E+02 | (m) |
| Approximate Width (Width of Blue Box) | $W_2$ | 3.30E+01 | (m) |

**5. PLUME CHARACTERISTICS CONT'D**

| | | | |
|---|---|---|---|
| Concentration of Contour Line in Blue Box | | 5.00E-03 | *(mg/L)* |
| Representative Concentration (OK to Override) | $C_{s2}$ | 5.00E-02 | *(mg/L)* Restore |
| Uncertainty in Plume Concentration Estimations | *± factor of* | 25 | ? |

**6. GENERAL**

| | | |
|---|---|---|
| Source Loading Starts in Year | 1966 | *(format: yyyy)* |
| Source Removed in Year | 1989 | *(format: yyyy)* |




See Release Period Results

| | | |
|---|---|---|
| from Year | 1996 | *(format: yyyy)* |
| to Year | 2150 | *(format: yyyy)* |
| in Intervals of | 2 | (yrs) |

**7. FIELD DATA FOR COMPARISON**

| Year | 2003 | 2004 | 2007 | 2008 | 2009 | 2010 | 2011 | 2013 |
|---|---|---|---|---|---|---|---|---|
| Concentration (mg/L) | 15 | 34.4 | 17 | 358 | 321 | 249 | 14.4 | 5.3 |
| Mass Discharge (g/day) | | | | | | | | |
| Mass (kg) | | | | | | | | |

**Next Step: Show Graph**

New Site/Clear Data | Paste Example | HELP

Save Data | Load Data

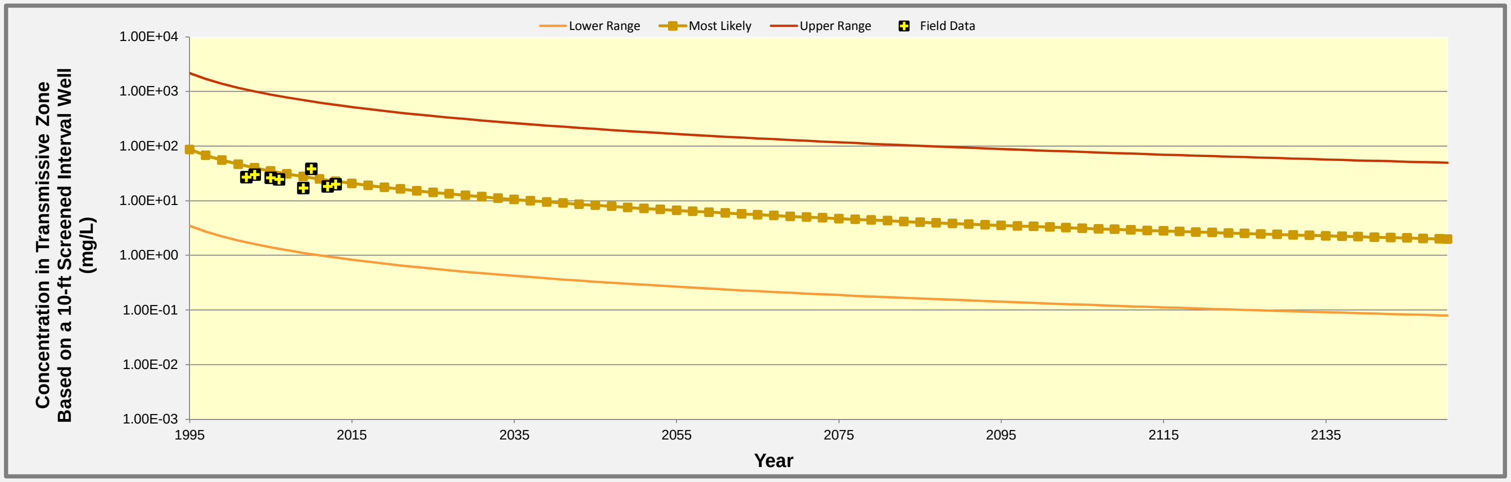
Return to Model Selection Screen | Return to Main Screen

Matrix Diffusion Toolbox
West Plume Area
INT UNIT
Tert-Butyl Alcohol

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Time (yr)** | **2115** | **2117** | **2119** | **2121** | **2123** | **2125** | **2127** | **2129** | **2131** | **2133** | **2135** | **2137** | **2139** | **2141** | **2143** | **2145** | **2147** | **2149** | **2150** |
| **Mass Discharge (g/day)** | **3.02** | **2.95** | **2.89** | **2.83** | **2.77** | **2.71** | **2.66** | **2.61** | **2.55** | **2.51** | **2.46** | **2.41** | **2.37** | **2.32** | **2.28** | **2.24** | **2.20** | **2.16** | **2.14** |
| **Mass (kg)** | **301.64** | **299.46** | **297.33** | **295.24** | **293.20** | **291.20** | **289.24** | **287.32** | **285.44** | **283.59** | **281.78** | **280.00** | **278.26** | **276.55** | **274.87** | **273.22** | **271.60** | **270.00** | **269.22** |
| **Concentration (mg/L)** | **2.80** | **2.74** | **2.68** | **2.62** | **2.57** | **2.52** | **2.47** | **2.42** | **2.37** | **2.32** | **2.28** | **2.24** | **2.19** | **2.15** | **2.12** | **2.08** | **2.04** | **2.00** | **1.99** |
| **Plume Magnitude** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** | **Mag 5** |

Note: Negative mass discharge values represent diffusion into the low-k zone from the transmissive zone. Positive values represent diffusion from the low-k zone into the transmissive zone.

***What's up with the gap?***




**Log** **Linear**

**Re-Plot Graph from Year** 1995 **to Year** 2100
*(format: yyyy)* *(format: yyyy)*

**Update Graph**

**Restore Original Interval** **Restore Original Graph**

**Next Step: Save Data**

**See Mass Discharge Results** **See Mass Results**

**Return to SRM Data Input** **Export/Print Data Table**

**Run Advanced Uncertainty Analysis**

**Return to Main Screen** ***HELP***

Matrix Diffusion Toolbox
West Plume Area
INT UNIT
Tert-Butyl Alcohol

## SRM Data Input Screen

*Matrix Diffusion Toolkit* *Version 1.2*

**DATA INPUT INSTRUCTIONS**

Enter value directly.

Value calculated by Toolkit. Do not enter data.

Site Location and ID: FLTG WEST Plume - INT UNIT

### 1. SYSTEM UNITS

(•) SI Units ( ) English Units

### 2. ANALYSIS TYPE

( ) Source Zone Analysis (•) Plume Analysis ( ) PRB Analysis ?

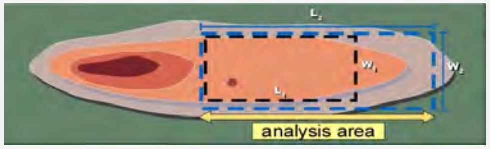
### 3. HYDROGEOLOGY

| | | | | |
|---|---|---|---|---|
| Low-k Zone Description | | INT | User Input | |
| Low-k Zone Total Porosity | $\Phi$ | 0.47 | (-) | |
| Transmissive Zone Darcy Velocity | $V_d$ | 9.52E-06 | (cm/sec) | Calculate Vd ? |

### 4. TRANSPORT - Low-k Zone

| | | | | |
|---|---|---|---|---|
| Key Constituent | | TBA | User Input | |
| Molecular Diffusion Coefficient in Free Water | $D_o$ | 1.14E-01 | (cm2/sec) | |
| Apparent Tortuosity Factor Exponent | $p$ | 1.10 | (-) | |
| Retardation Factor | $R$ | 1.01 | (-) | Calculate R ? |

### 5. PLUME CHARACTERISTICS



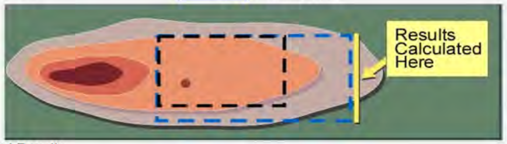

| | | | | |
|---|---|---|---|---|
| High Concentration Zone (Black Box in Picture) | | | | |
| Approximate Length (Length of Black Box) | $L_1$ | 8.00E+01 | (m) | ? |
| Approximate Width (Width of Black Box) | $W_1$ | 2.70E+01 | (m) | |
| Highest Historical Concentration in Black Box | | 7.50E+01 | (mg/L) | |
| Concentration of Contour Line in Black Box | | 1.00E+01 | (mg/L) | |
| Representative Concentration (OK to Override) | $C_{s1}$ | 1.20E+01 | (mg/L) | Restore |
| Next Highest Concentration Zone (Blue Box in Picture) | | | | |
| Approximate Length (Length of Blue Box) | $L_2$ | 1.50E+02 | (m) | |
| Approximate Width (Width of Blue Box) | $W_2$ | 4.30E+01 | (m) | |

### 5. PLUME CHARACTERISTICS CONT'D

| | | | | |
|---|---|---|---|---|
| Concentration of Contour Line in Blue Box | | 2.20E+00 | (mg/L) | |
| Representative Concentration (OK to Override) | $C_{s2}$ | 4.69E+00 | (mg/L) | Restore |
| Uncertainty in Plume Concentration Estimations | ± factor of | 25 | | ? |

### 6. GENERAL

| | | |
|---|---|---|
| Source Loading Starts in Year | 1966 | (format: yyyy) |
| Source Removed in Year | 1989 | (format: yyyy) |




| | | |
|---|---|---|
| See Release Period Results | | |
| from Year | 1995 | (format: yyyy) |
| to Year | 2150 | (format: yyyy) |
| in Intervals of | 2 | (yrs) |

### 7. FIELD DATA FOR COMPARISON

| Year | 2012 | 2002 | 2003 | 2009 | 2005 | 2006 | 2010 | 2013 |
|---|---|---|---|---|---|---|---|---|
| Concentration (mg/L) | 18.2 | 27 | 30 | 17.1 | 26.3 | 24.8 | 38.3 | 20 |
| Mass Discharge (g/day) | | | | | | | | |
| Mass (kg) | | | | | | | | |

**Next Step: Show Graph**

New Site/Clear Data | Paste Example | HELP

Save Data | Load Data

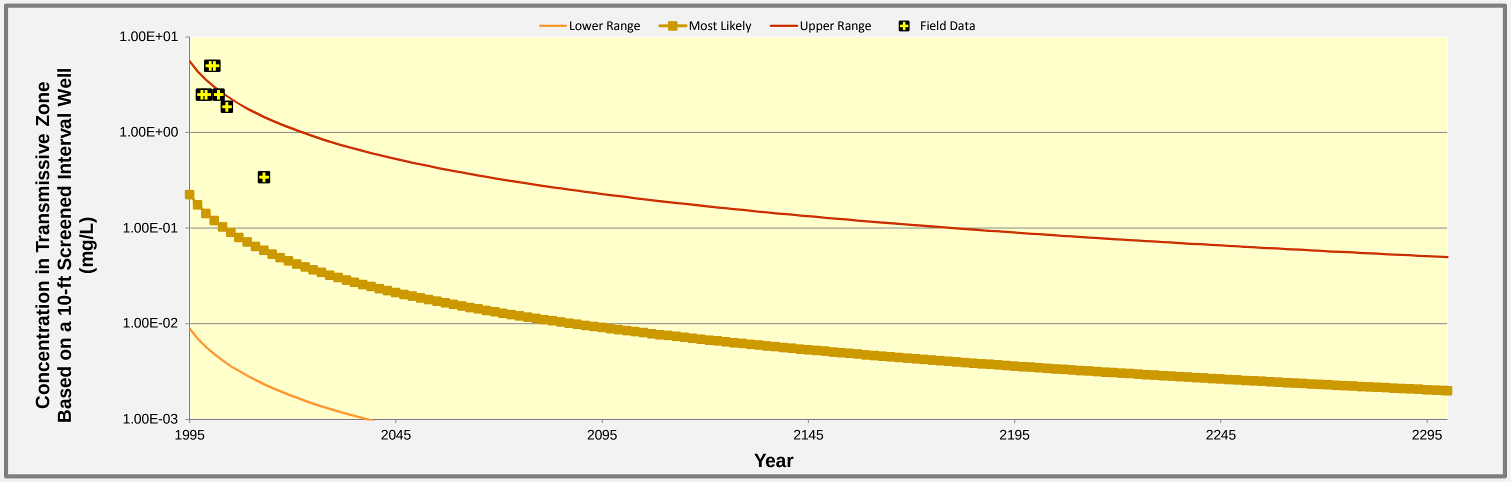
Return to Model Selection Screen | Return to Main Screen

Matrix Diffusion Toolbox
Central Plume Area
S1 UNIT
BENZENE

| Time (yr) | 2135 | 2137 | 2139 | 2141 | 2143 | 2145 | 2147 | 2149 | 2151 | 2153 | 2155 | 2157 | 2159 | 2161 | 2163 | 2165 | 2167 | 2169 | 2171 | 2173 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mass Discharge (g/day) | 0.0010 | 0.0009 | 0.0009 | 0.0009 | 0.0009 | 0.0009 | 0.0009 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0007 | 0.0007 | 0.0007 | 0.0007 | 0.0007 | 0.0007 |
| Mass (kg) | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Concentration (mg/L) | 0.0058 | 0.0057 | 0.0056 | 0.0055 | 0.0054 | 0.0053 | 0.0052 | 0.0051 | 0.0050 | 0.0050 | 0.0049 | 0.0048 | 0.0047 | 0.0046 | 0.0046 | 0.0045 | 0.0044 | 0.0044 | 0.0043 | 0.0042 |
| Plume Magnitude | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 | Mag 1 |

Note: Negative mass discharge values represent diffusion into the low-k zone from the transmissive zone. Positive values represent diffusion from the low-k zone into the transmissive zone.

What's up with the gap?




Log Linear

Re-Plot Graph from Year 2000 to Year 2100
(format: yyyy) (format: yyyy)

Update Graph

Restore Original Interval | Restore Original Graph

**Next Step: Save Data**

See Mass Discharge Results | See Mass Results

Return to SRM Data Input | Export/Print Data Table

Run Advanced Uncertainty Analysis

Return to Main Screen | HELP

Matrix Diffusion Toolbox
Central Plume Area S1 UNIT
BENZENE

## SRM Data Input Screen

*Matrix Diffusion Toolkit* *Version 1.2*

Site Location and ID: FLTG Central Plume - S1 UNIT

**DATA INPUT INSTRUCTIONS**

Enter value directly.
Value calculated by Toolkit. Do not enter data.

**1. SYSTEM UNITS**

◉ SI Units ○ English Units

**2. ANALYSIS TYPE**

○ Source Zone Analysis ◉ Plume Analysis ○ PRB Analysis ?

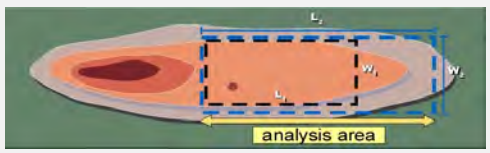
**3. HYDROGEOLOGY**

| | | | |
|---|---|---|---|
| Low-k Zone Description | | Clay | Clay |
| Low-k Zone Total Porosity | $\Phi$ | 0.47 | (-) |
| Transmissive Zone Darcy Velocity | $V_d$ | 0.0000031 | (cm/sec) Calculate Vd ? |

**4. TRANSPORT - Low-k Zone**

| | | | |
|---|---|---|---|
| Key Constituent | | Benzene | Benzene |
| Molecular Diffusion Coefficient in Free Water | $D_o$ | 9.80E-10 | (m2/sec) |
| Apparent Tortuosity Factor Exponent | $p$ | 1.10 | (-) |
| Retardation Factor | $R$ | 8.10 | (-) Calculate R ? |

**5. PLUME CHARACTERISTICS**




| | | | |
|---|---|---|---|
| High Concentration Zone (Black Box in Picture) | | | |
| Approximate Length (Length of Black Box) | $L_1$ | 1.60E+01 | (m) ? |
| Approximate Width (Width of Black Box) | $W_1$ | 1.60E+01 | (m) |
| Highest Historical Concentration in Black Box | | 5.00E+00 | (mg/L) |
| Concentration of Contour Line in Black Box | | 5.00E-01 | (mg/L) |
| Representative Concentration (OK to Override) | $C_{s1}$ | 1.58E+00 | (mg/L) Restore |
| Next Highest Concentration Zone (Blue Box in Picture) | | | |
| Approximate Length (Length of Blue Box) | $L_2$ | 1.00E+02 | (m) |
| Approximate Width (Width of Blue Box) | $W_2$ | 2.00E+01 | (m) |

**5. PLUME CHARACTERISTICS CONT'D**

| | | | |
|---|---|---|---|
| Concentration of Contour Line in Blue Box | | 5.00E-02 | (mg/L) |
| Representative Concentration (OK to Override) | $C_{s2}$ | 1.58E-01 | (mg/L) Restore |
| Uncertainty in Plume Concentration Estimations | ± factor of | 25 | ? |

**6. GENERAL**

| | | |
|---|---|---|
| Source Loading Starts in Year | 1966 | (format: yyyy) |
| Source Removed in Year | 1989 | (format: yyyy) |


| | | |
|---|---|---|
| See Release Period Results | | |
| from Year | 1995 | (format: yyyy) |
| to Year | 2300 | (format: yyyy) |
| in Intervals of | 2 | (yrs) |

**7. FIELD DATA FOR COMPARISON**

| Year | 1993 | 1998 | 1999 | 2000 | 2001 | 2002 | 2004 | 2013 |
|---|---|---|---|---|---|---|---|---|
| Concentration (mg/L) | 1.055 | 2.5 | 2.5 | 5 | 5 | 2.5 | 1.86 | 0.34 |
| Mass Discharge (g/day) | | | | | | | | |
| Mass (kg) | | | | | | | | |

**Next Step: Show Graph**

New Site/Clear Data | Paste Example | HELP
Save Data | Load Data
Return to Model Selection Screen | Return to Main Screen

Matrix Diffusion Toolbox
Summary of Model Input Parameters

| | UNITS | Area Modeled | | | |
|---|---|---|---|---|---|
| | | Central S1 | Central Plume - INT | West Plmue - INT | NOTES/Source: |
| **HYDROGEOLOGY** | | | | | |
| Low-k Zone Description | --- | C1 Clay | INT clay/Silt | INT Clay/Silt | |
| Low-k Zone Total Porosity | --- | 0.47 | 0.47 | 0.47 | Payne etal.,2008 Table 2.3 |
| Hydraulic conductivity (K) (cm/s) | cm/sec | 7.056E-03 | 1.058E-03 | 1.058E-03 | 3 ft/day in INT; 20 ft/day in S1 |
| Hydraulic gradient | | 0.002 | 0.003 | 0.009 | |
| Gradient location | | S1-140-> S1-141 (2013) | INT-153->INT262 (2013) | INT-233->INT-101 (2013) | |
| Transmissive Zone Darcy Velocity ($V_d$) | cm/sec | 1.411E-05 | 3.175E-06 | 9.525E-06 | |

| | | COC Specific Parameters | | | |
|---|---|---|---|---|---|
| Parameter | UNITS | 1,2-DCA | Benzene | TBA | |
| **TRANSPORT - Low-k Zone** | | | | | |
| Molecular Diffusion Coefficient in Free Water | $cm^2/sec$ | 1.09E-05 | 9.80E-06 | 1.03E-05 | Calculated values based on WATERS9 (US EPA, 2001) |
| Apparent Tortuosity Factor Exponent | | 1.1 | 1.1 | 1.1 | Model default |
| Retardation Factor | | 3.3 | 8.1 | 1.01 (calculated) | AHA, DNAPL STUDY RISK EVALUATION, APRIL 1994 |

NOTES:
TBA retardation factor calculated by model using bulk density, Koc, and foc data.

# Concentration Versus Time Plots

*Appendix G*

*April 2, 2014*

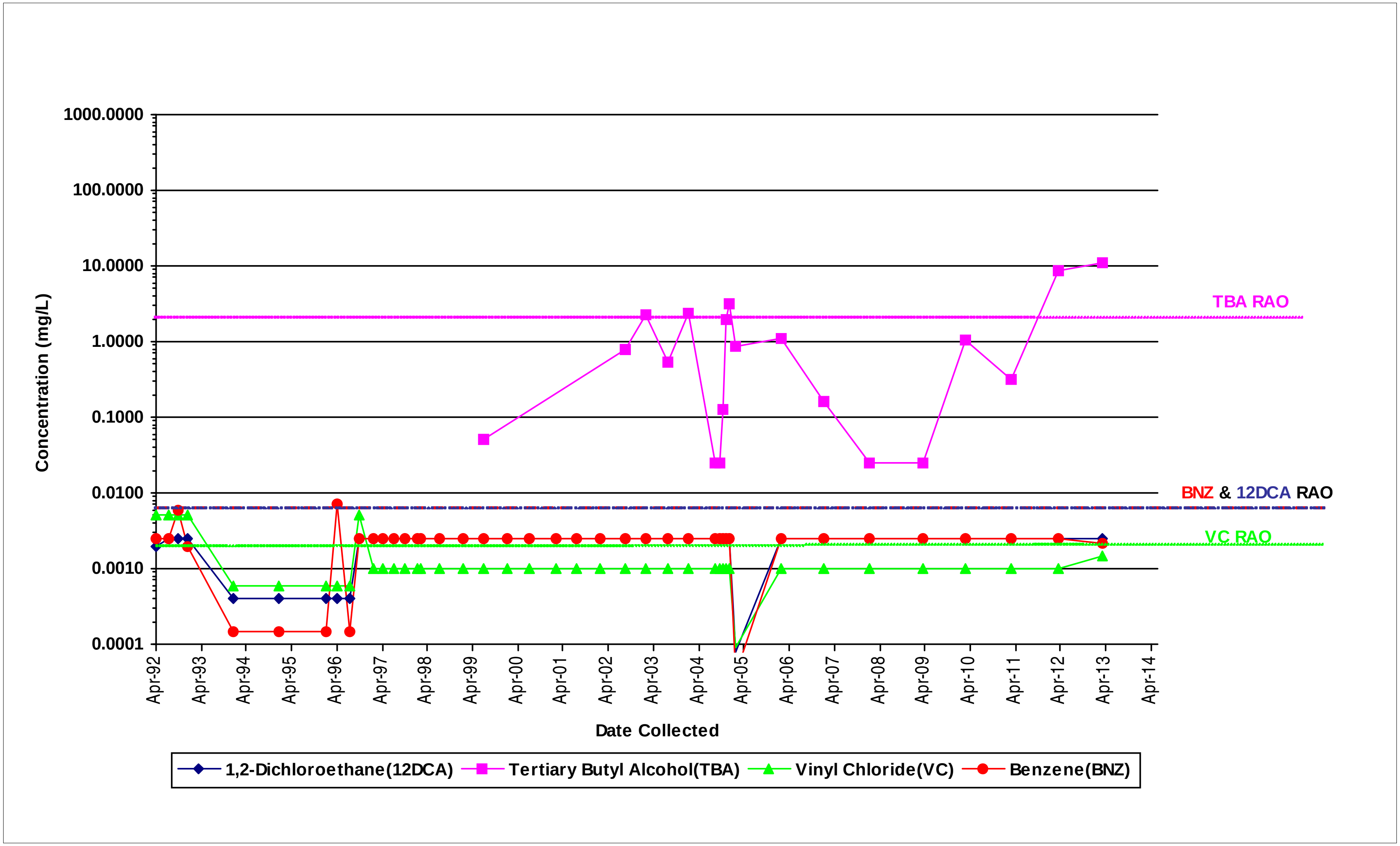
*Project No. 0234672*

**Environmental Resources Management**
CityCentre Four
840 West Sam Houston Parkway North, Suite 600
Houston, Texas 77024-3920
281-600-1000

**CENTRAL PLUME AREA**

**Unit Screened: S1**

## Well: FLTG-014




Not Detected results are graphed as 1/2 the laboratory reporting limit.

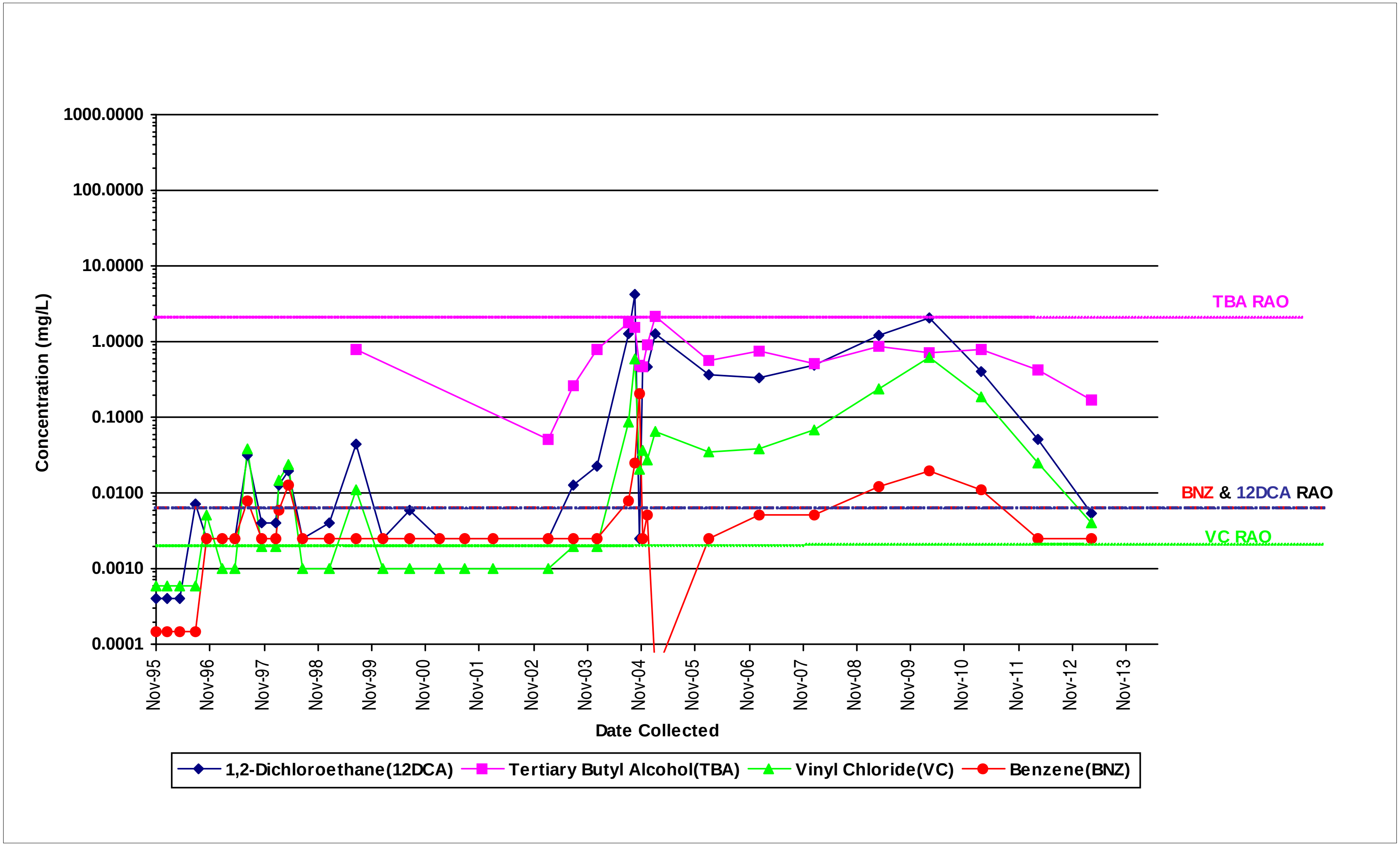
Ground Water Progress Graph

French Limited Superfund Site

**CENTRAL PLUME AREA**

**Unit Screened: S1**

**Well: S1-106A**




Not Detected results are graphed as 1/2 the laboratory reporting limit.

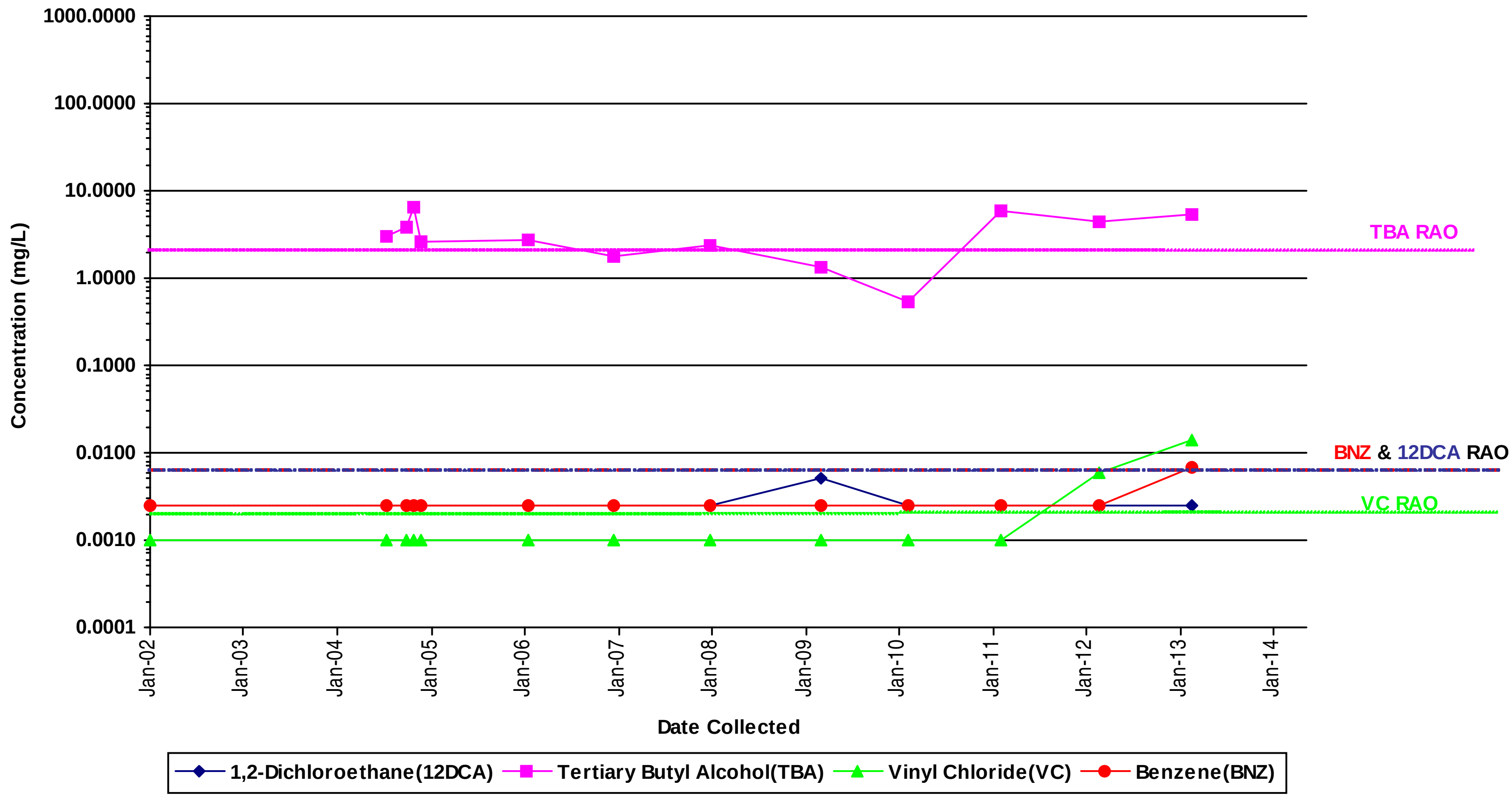
Ground Water Progress Graph

French Limited Superfund Site

**CENTRAL PLUME AREA**

**Unit Screened: S1**

## Well: S1-148

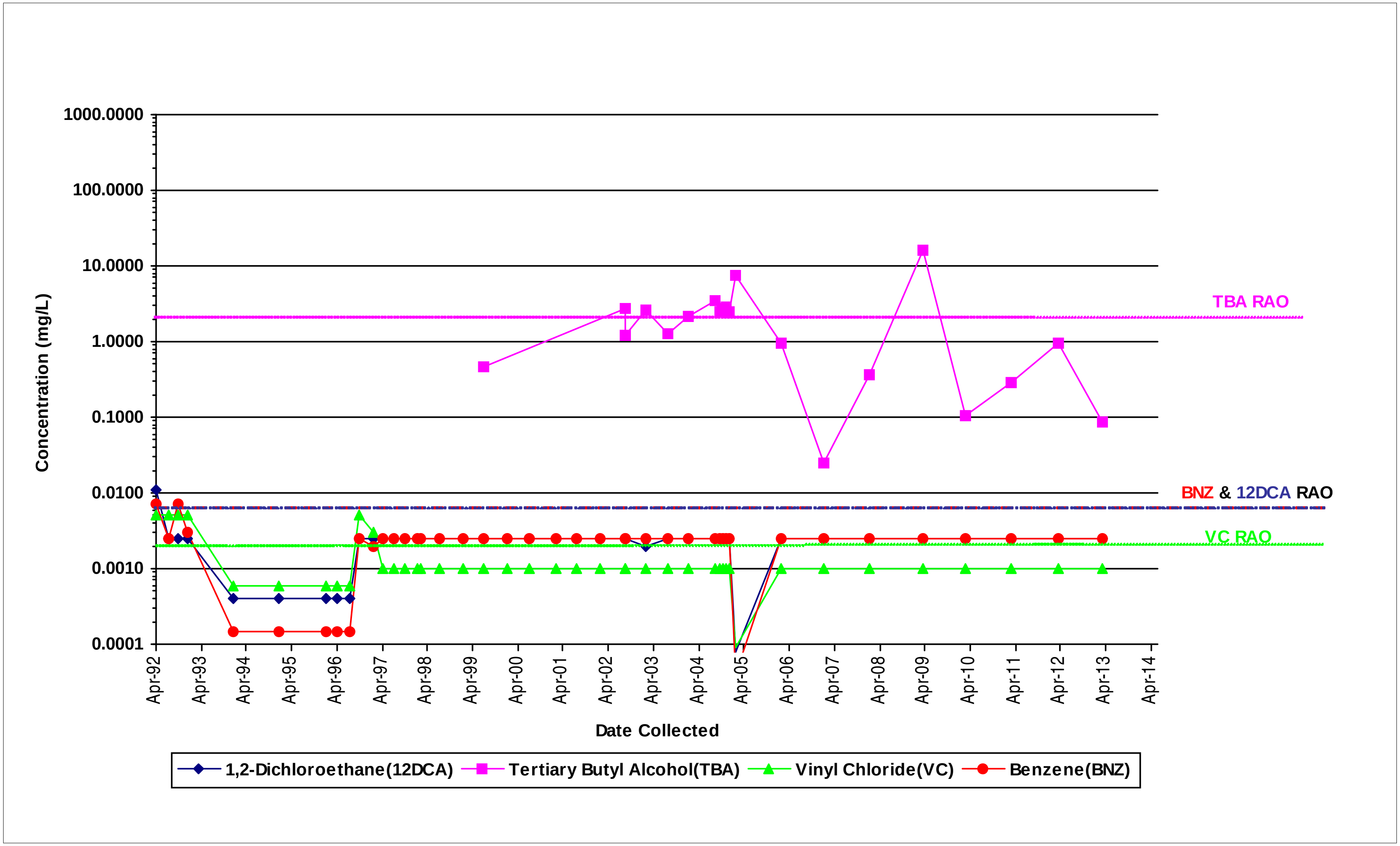



Not Detected results are graphed as 1/2 the laboratory reporting limit.

**CENTRAL PLUME AREA**

**Unit Screened: INT**

## Well: FLTG-013



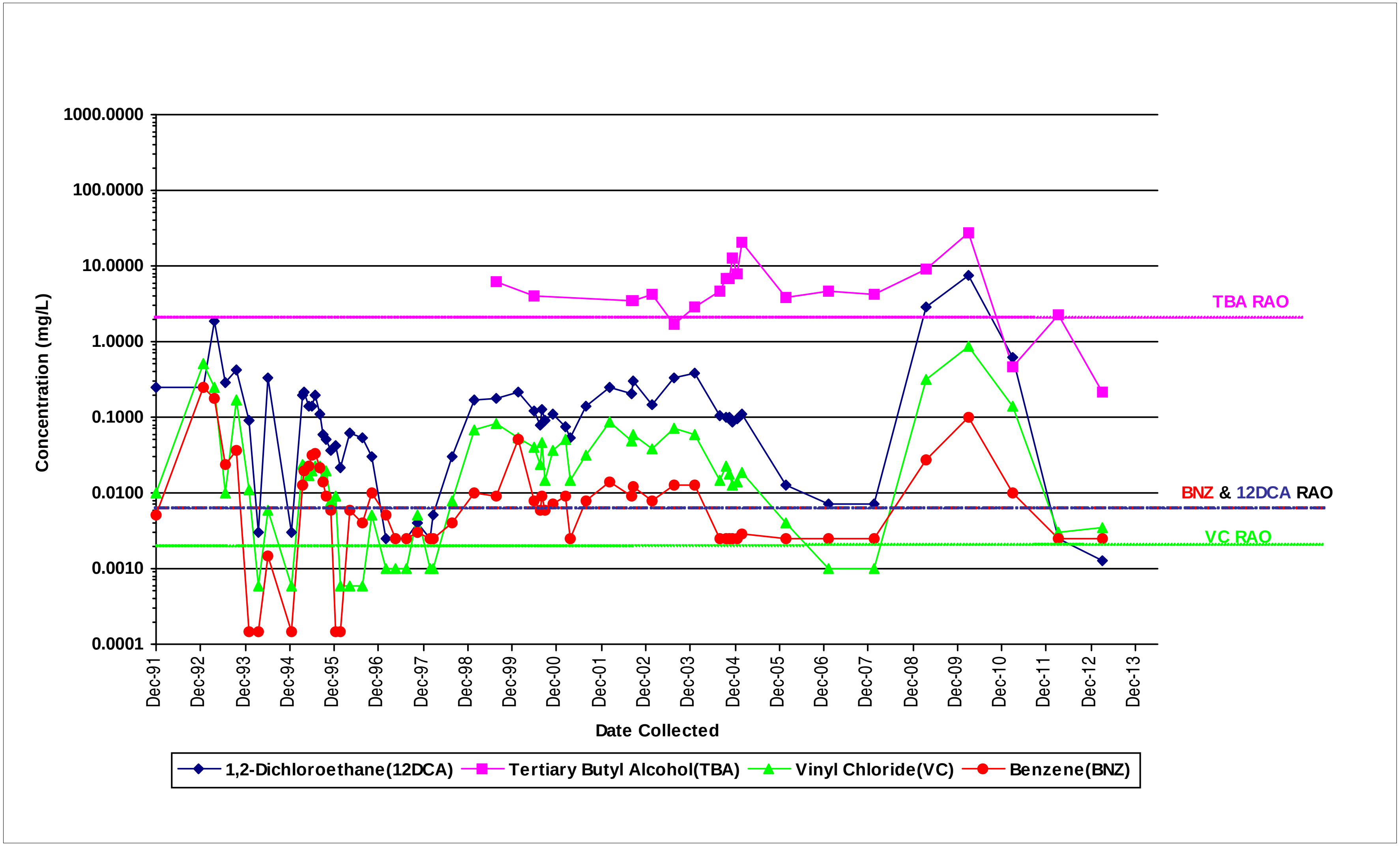

Not Detected results are graphed as 1/2 the laboratory reporting limit.

Ground Water Progress Graph French Limited Superfund Site

**CENTRAL PLUME AREA**

**Unit Screened: INT**

## Well: INT-106




Not Detected results are graphed as 1/2 the laboratory reporting limit.

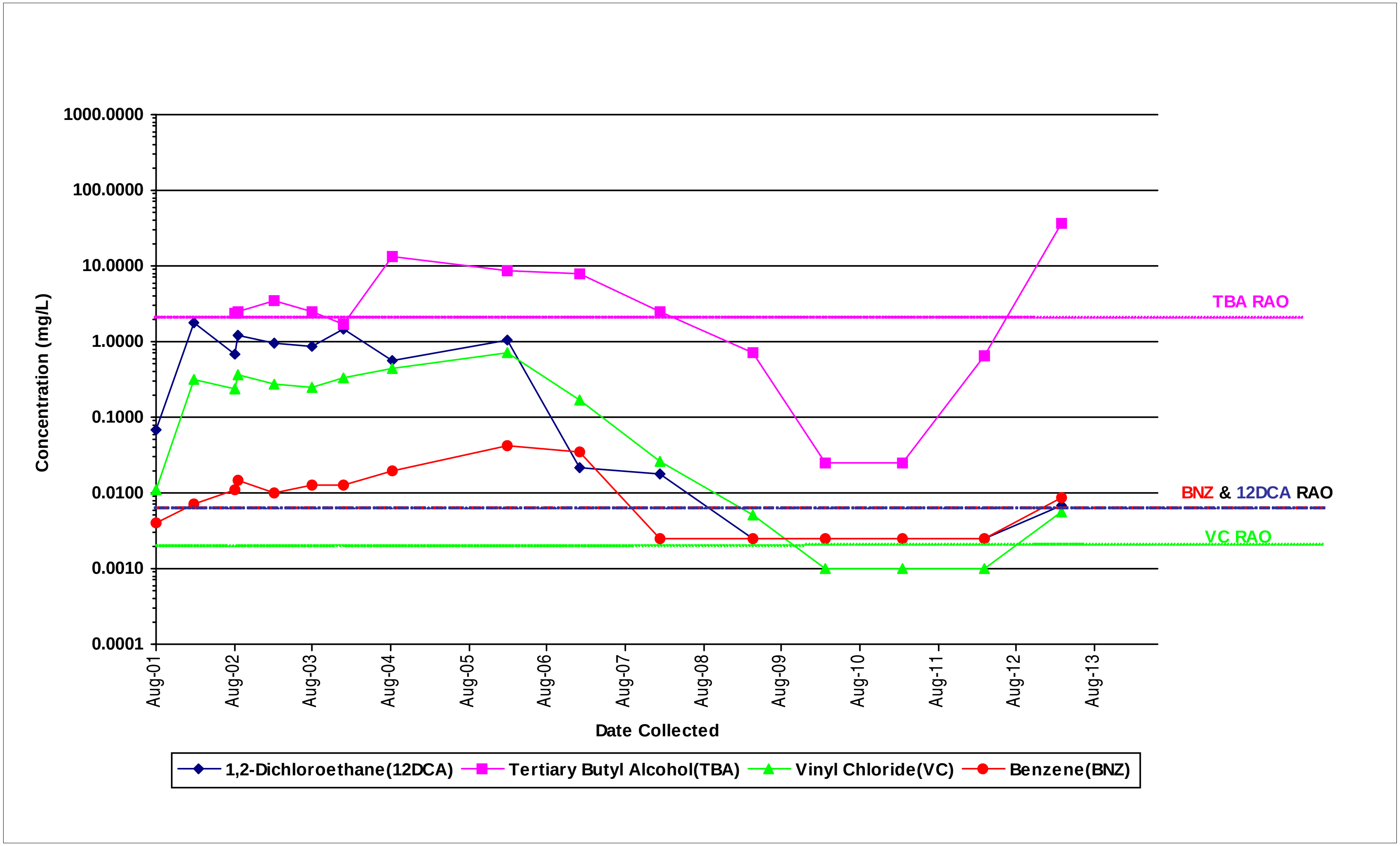
Ground Water Progress Graph

French Limited Superfund Site

**CENTRAL PLUME AREA**

**Unit Screened: INT**

## Well: INT-169




Not Detected results are graphed as 1/2 the laboratory reporting limit.

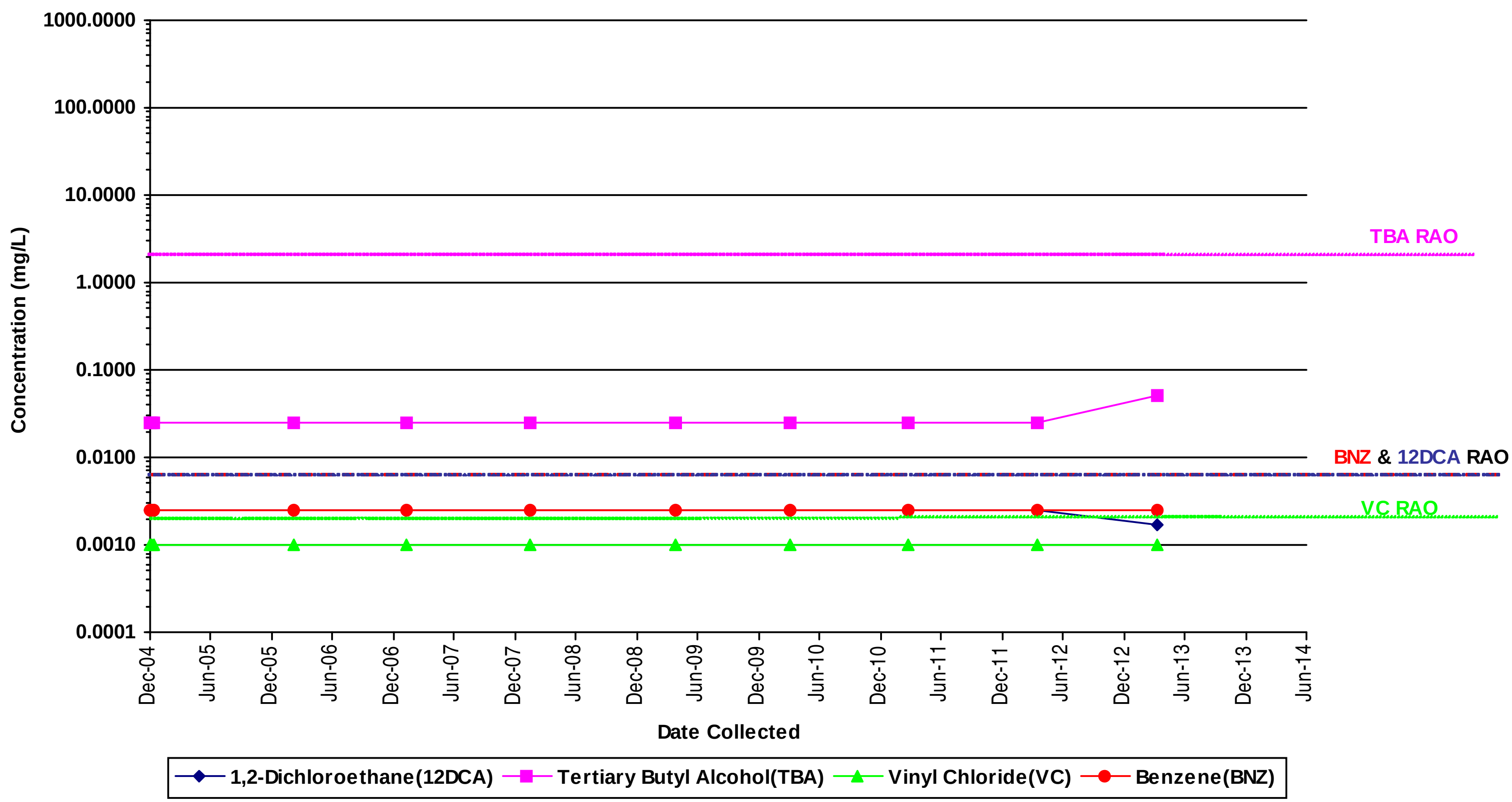
Ground Water Progress Graph

French Limited Superfund Site

**CENTRAL PLUME AREA**

**Unit Screened: INT**

**Well: INT-262**

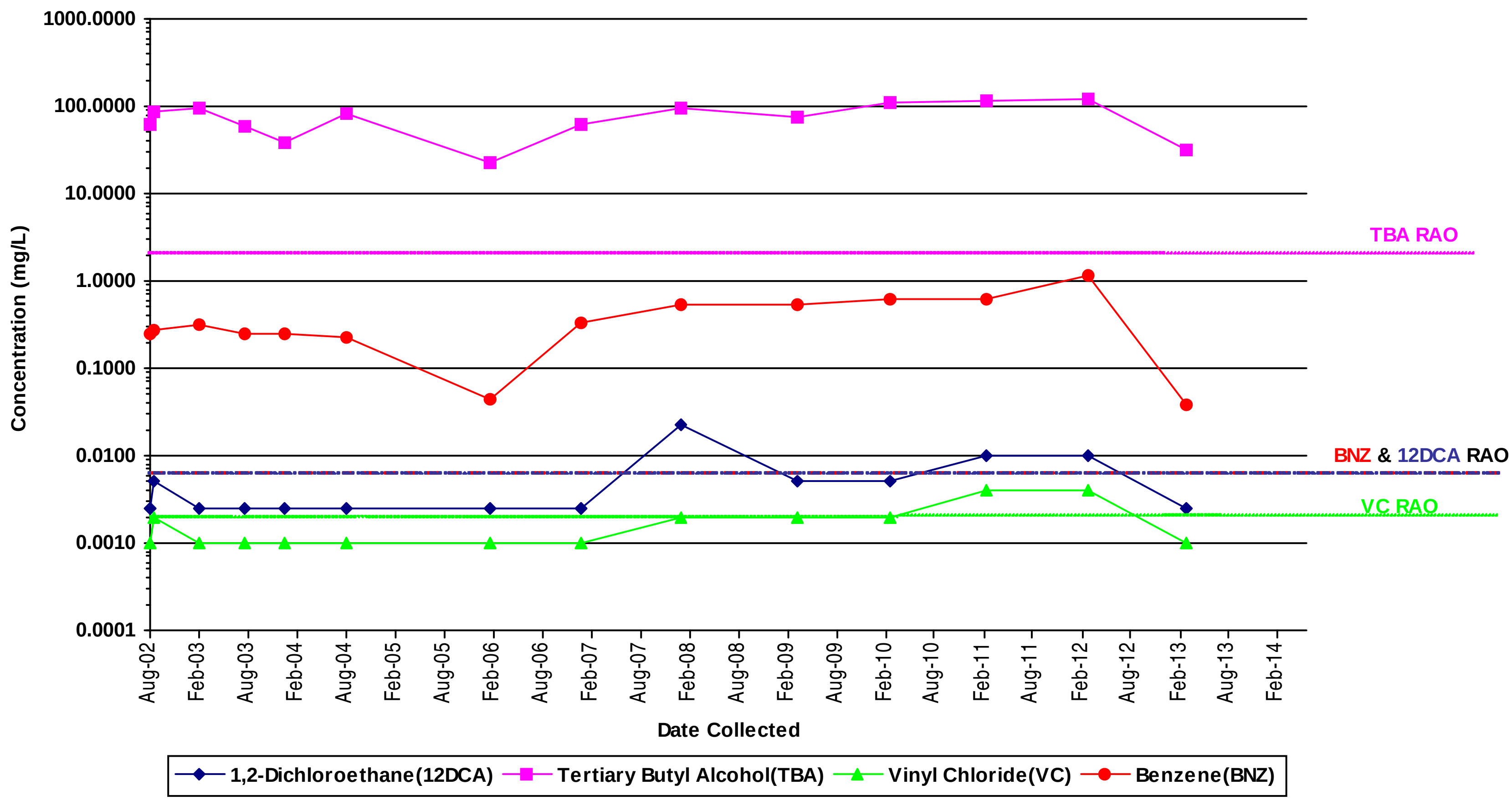



Not Detected results are graphed as 1/2 the laboratory reporting limit.

**EAST PLUME AREA**

**Unit Screened: S1**

## Well: S1-064




Not Detected results are graphed as 1/2 the laboratory reporting limit.

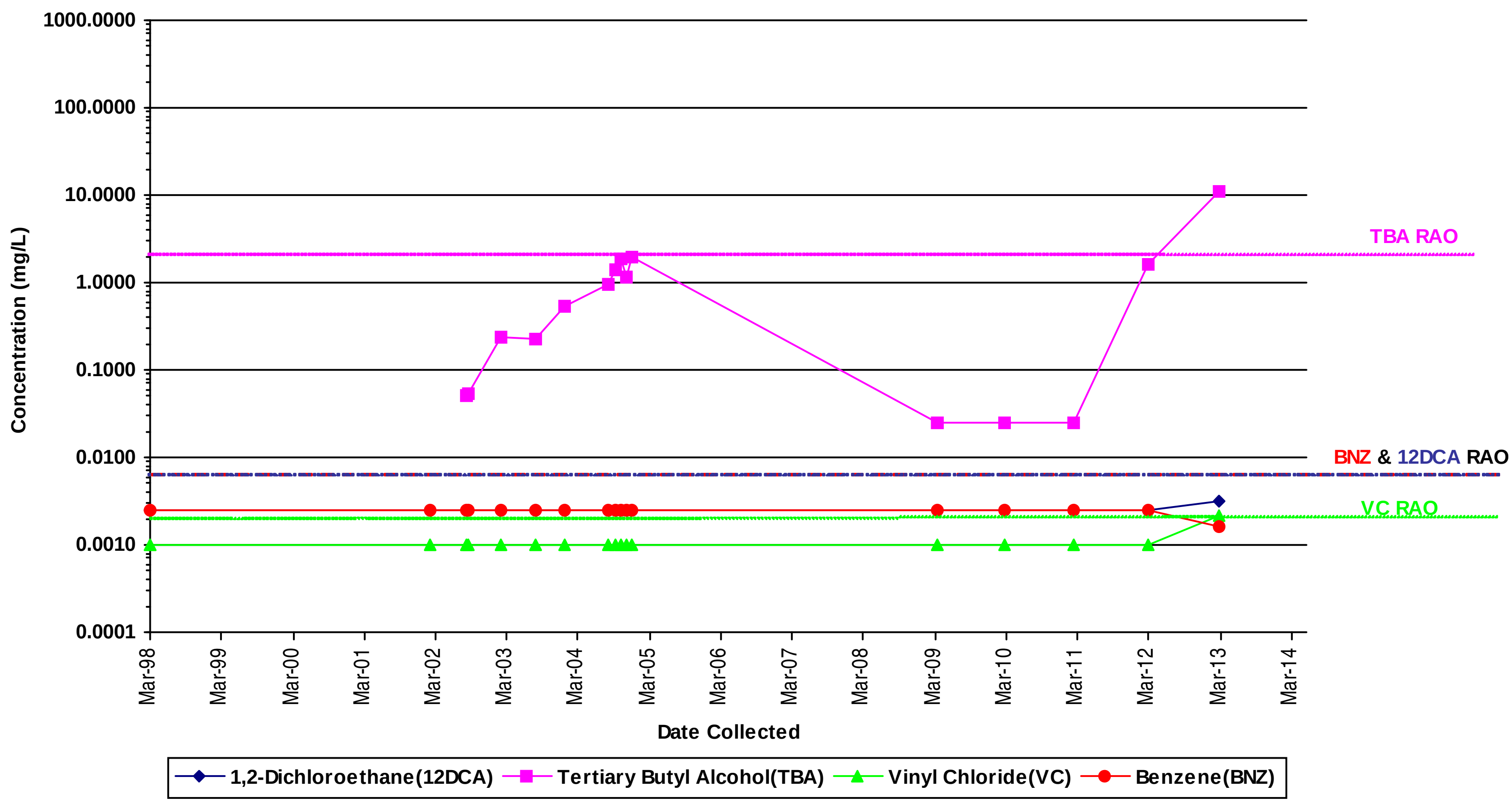
Ground Water Progress Graph

French Limited Superfund Site

**EAST PLUME AREA**

**Unit Screened: S1**

## Well: S1-136




Not Detected results are graphed as 1/2 the laboratory reporting limit.

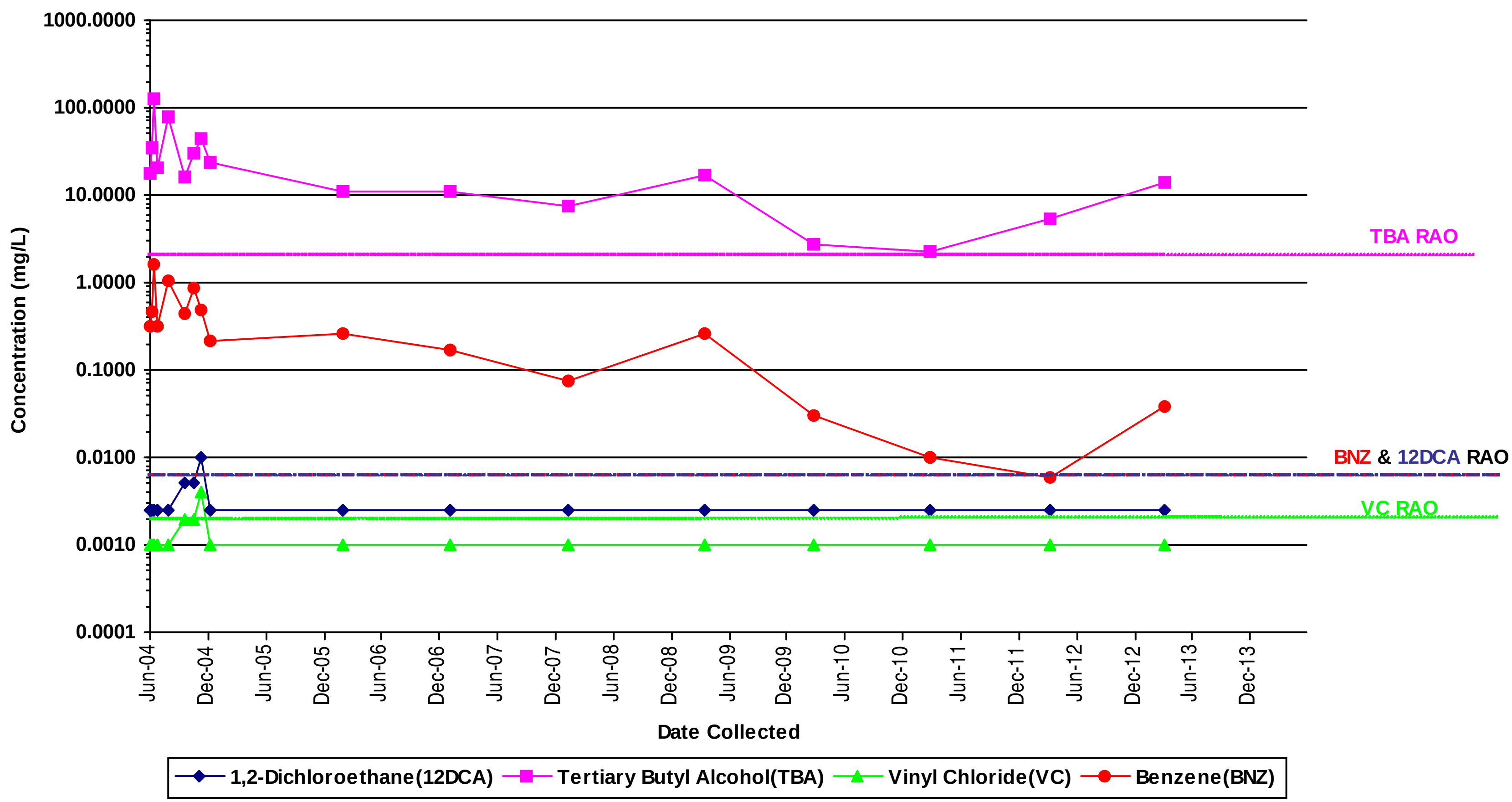
Ground Water Progress Graph

French Limited Superfund Site

**EAST PLUME AREA**

**Unit Screened: S1**

## Well: S1-161




Not Detected results are graphed as 1/2 the laboratory reporting limit.

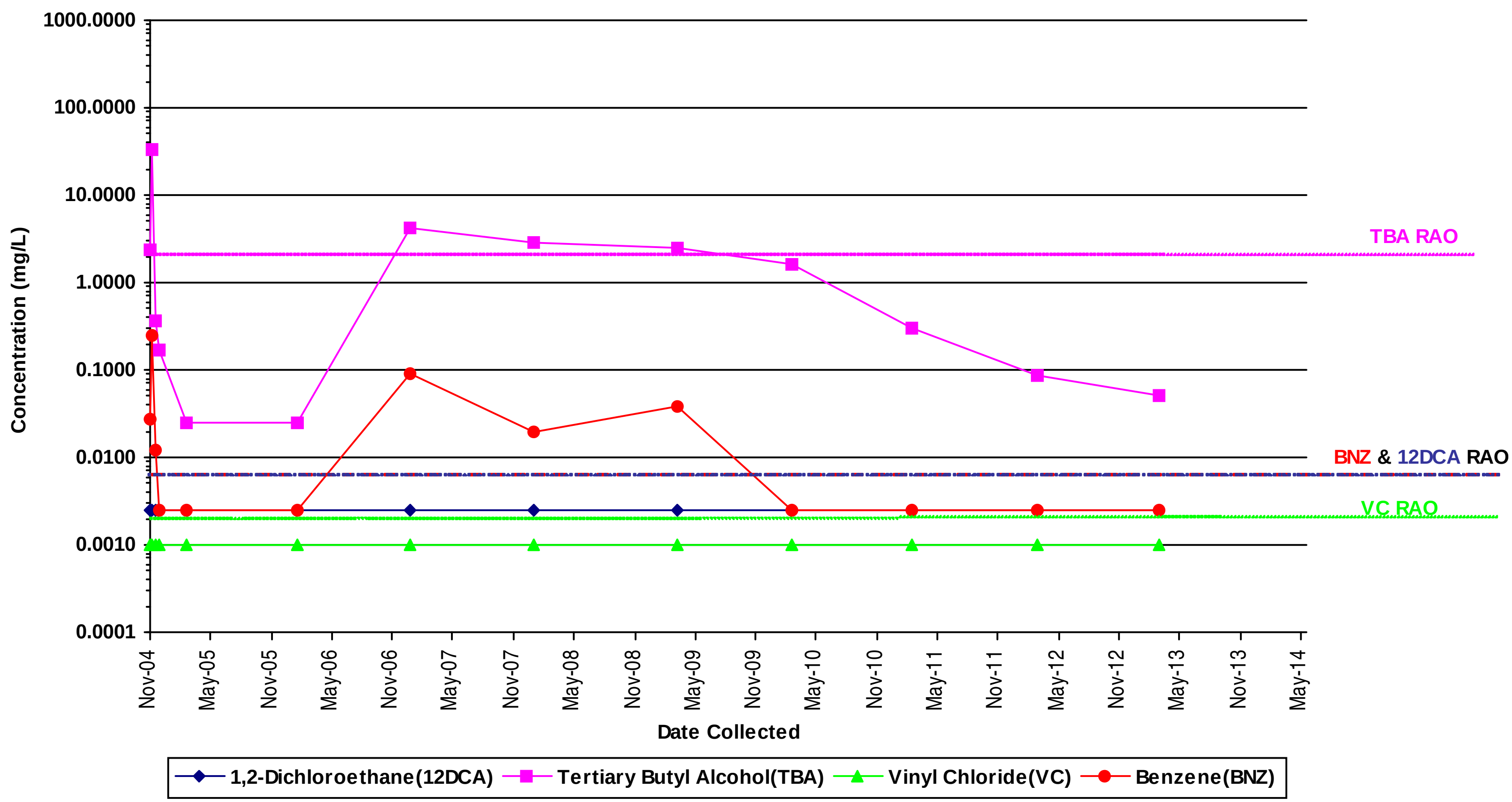
Ground Water Progress Graph

French Limited Superfund Site

**EAST PLUME AREA**

**Unit Screened: S1**

**Well: S1-165**




Not Detected results are graphed as 1/2 the laboratory reporting limit.

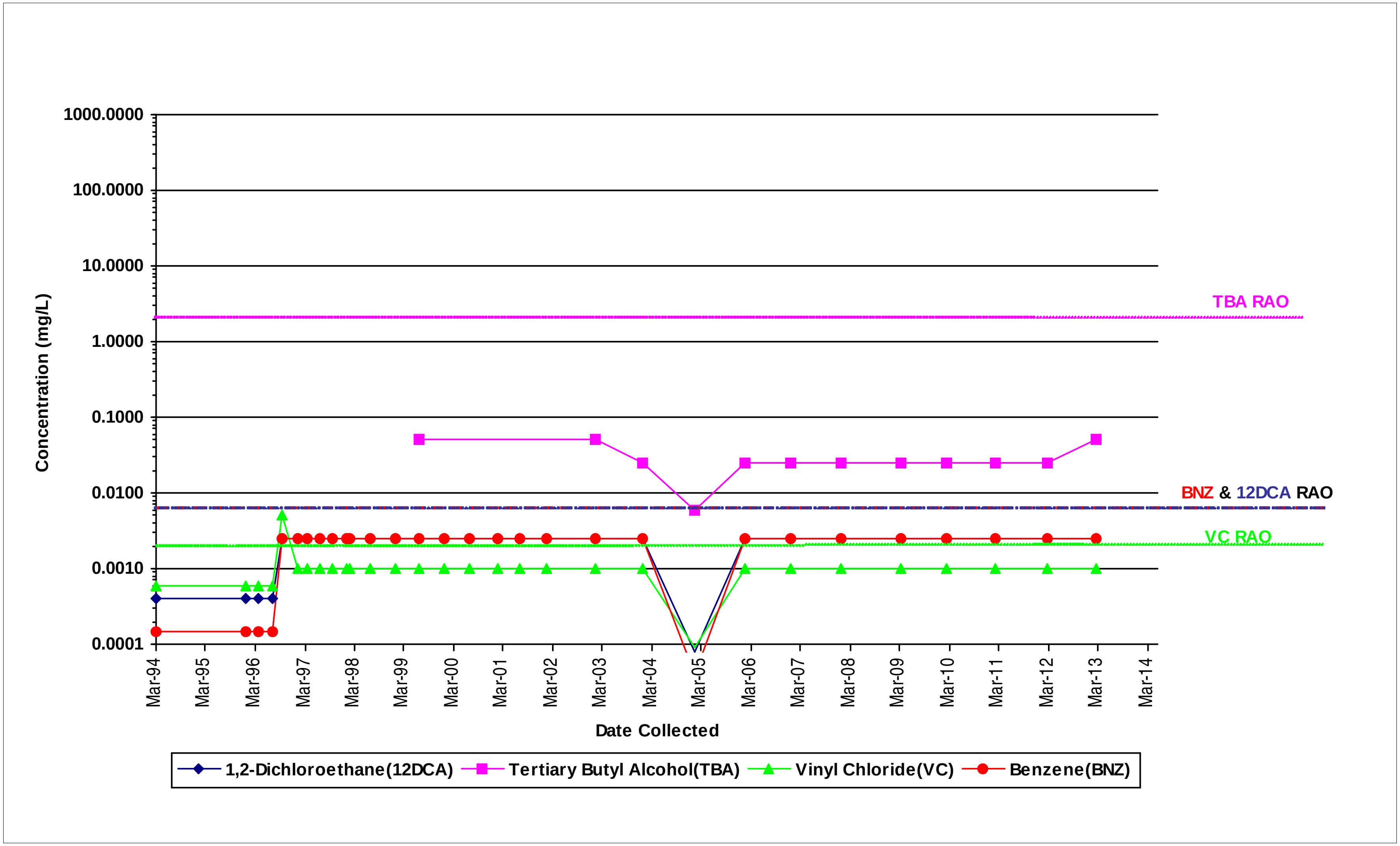
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: S1**

**Well: S1-033**




Not Detected results are graphed as 1/2 the laboratory reporting limit.

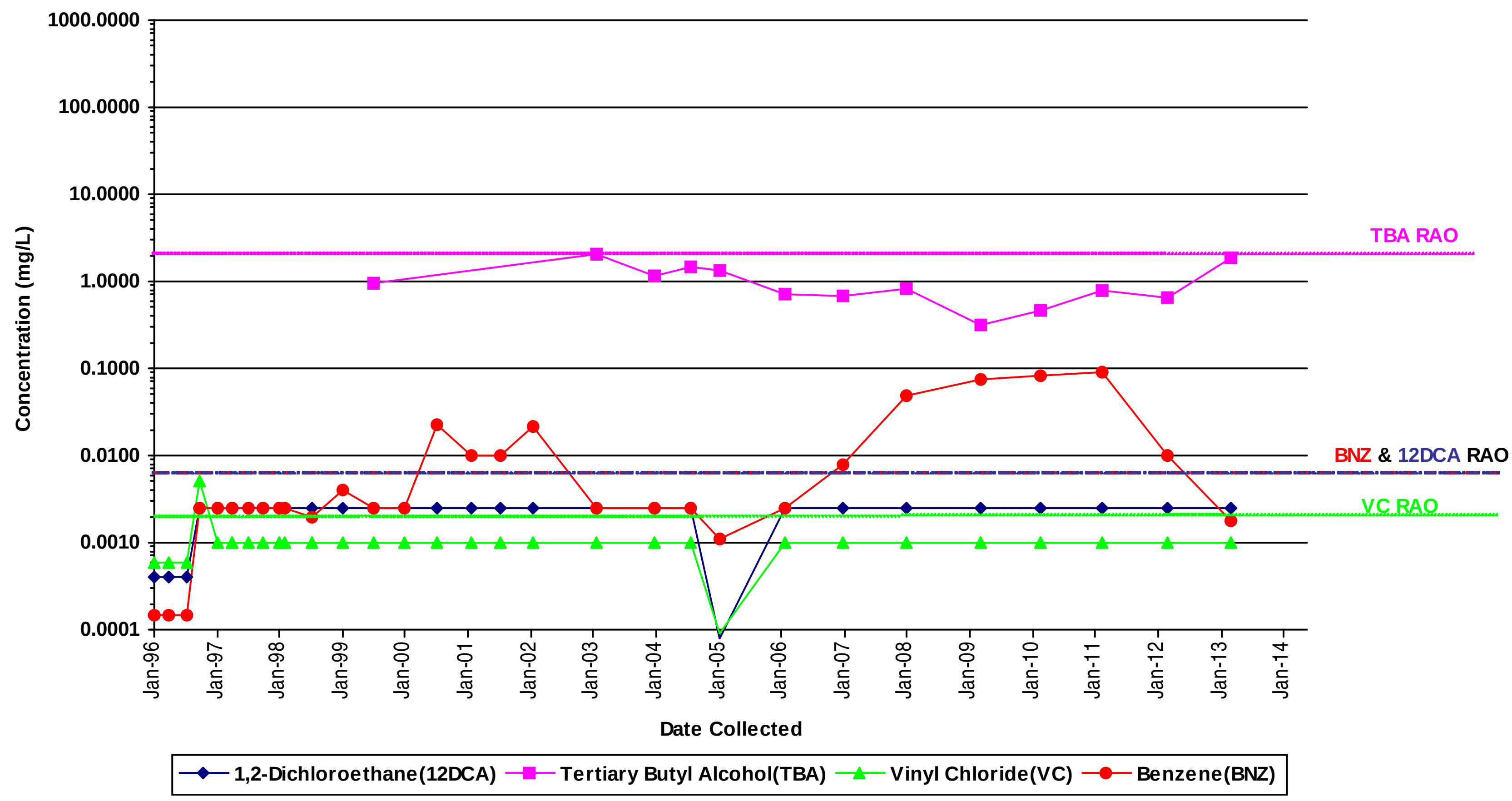
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: S1**

## Well: S1-051-P-3




Not Detected results are graphed as 1/2 the laboratory reporting limit.

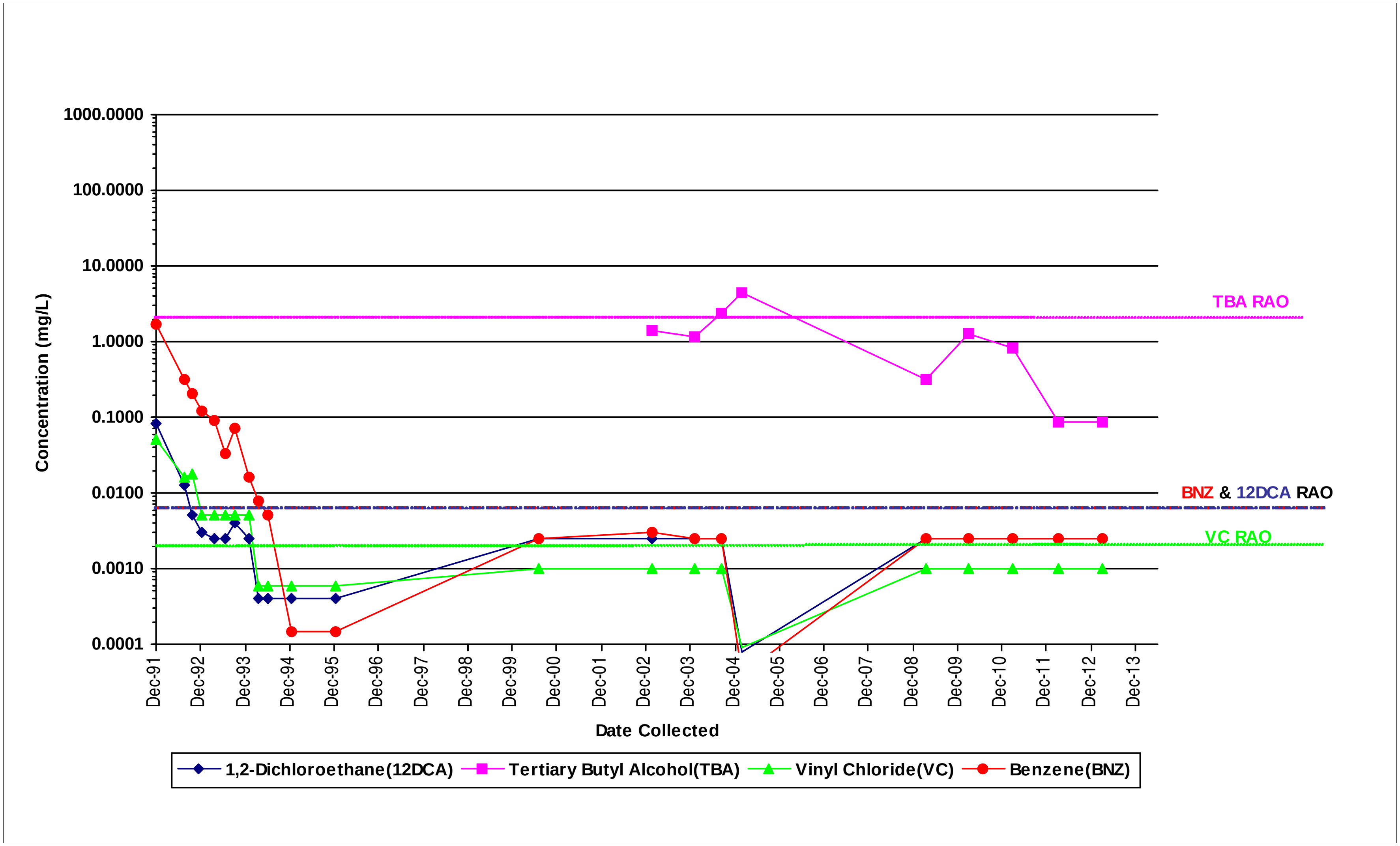
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: S1**

## Well: S1-111




Not Detected results are graphed as 1/2 the laboratory reporting limit.

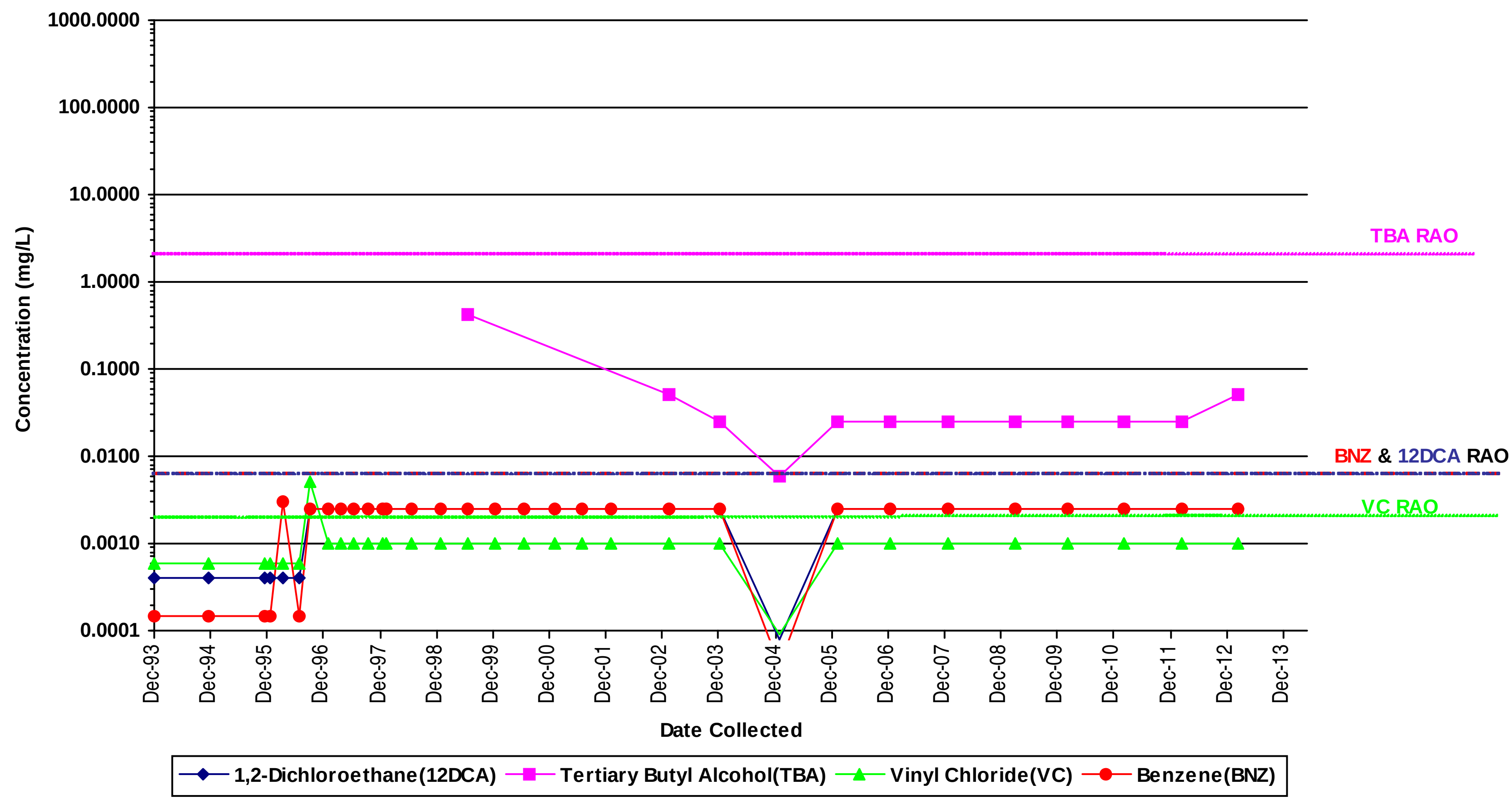
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: S1**

## Well: S1-135

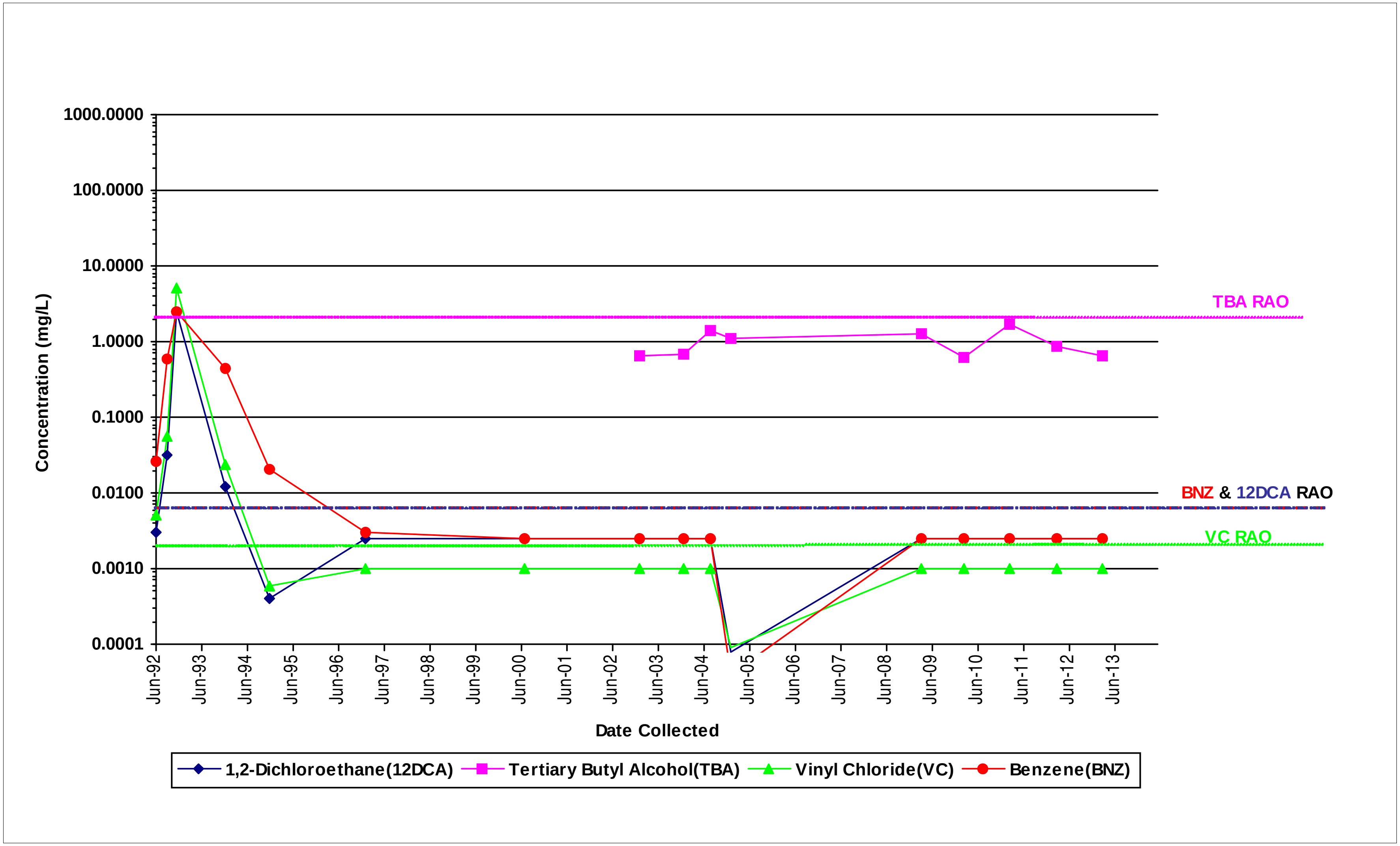



Not Detected results are graphed as 1/2 the laboratory reporting limit.

**WEST PLUME AREA**

**Unit Screened: INT**

## Well: INT-059-P-2




Not Detected results are graphed as 1/2 the laboratory reporting limit.

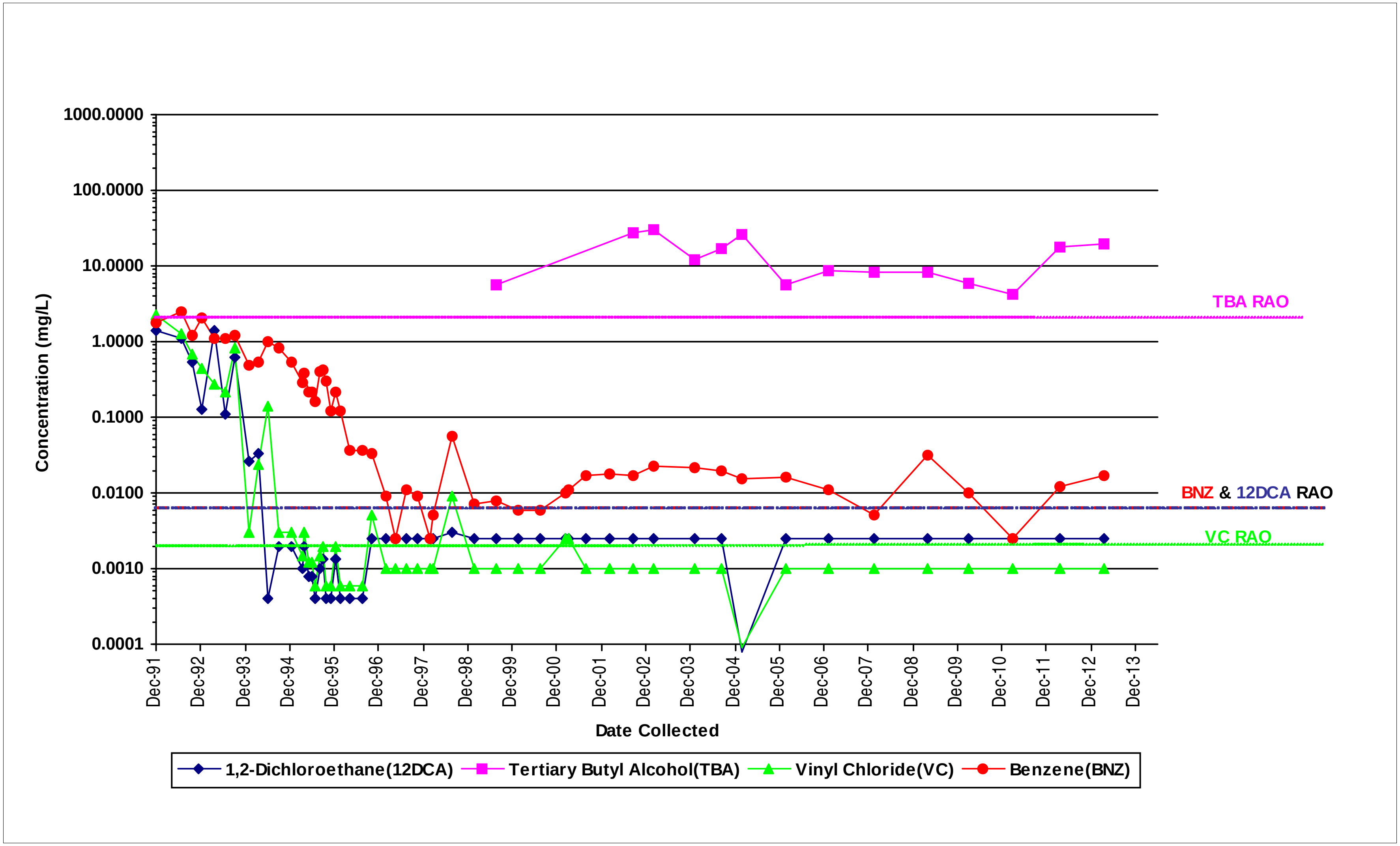
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: INT**

## Well: INT-101




Not Detected results are graphed as 1/2 the laboratory reporting limit.

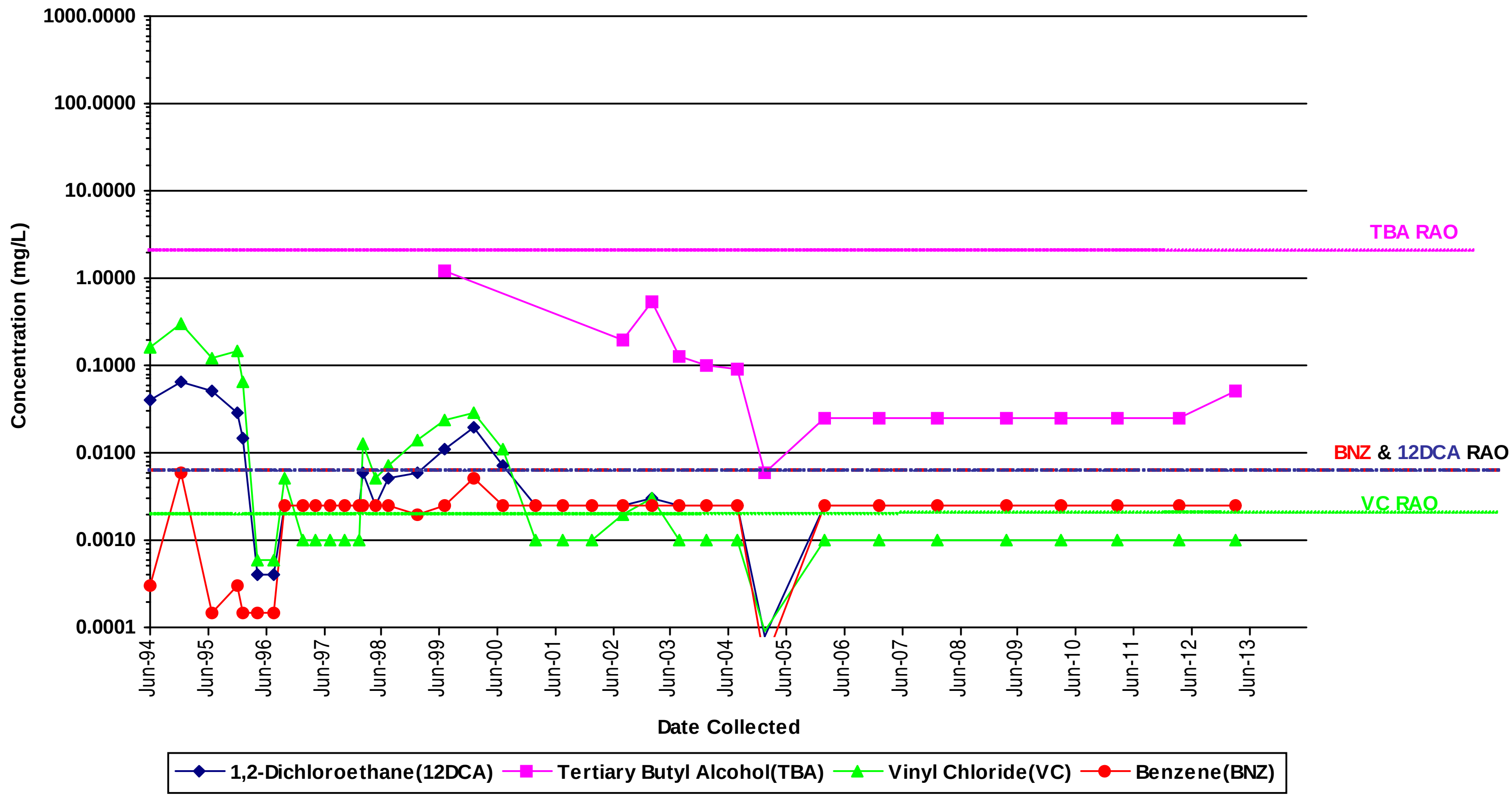
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: INT**

## Well: INT-135

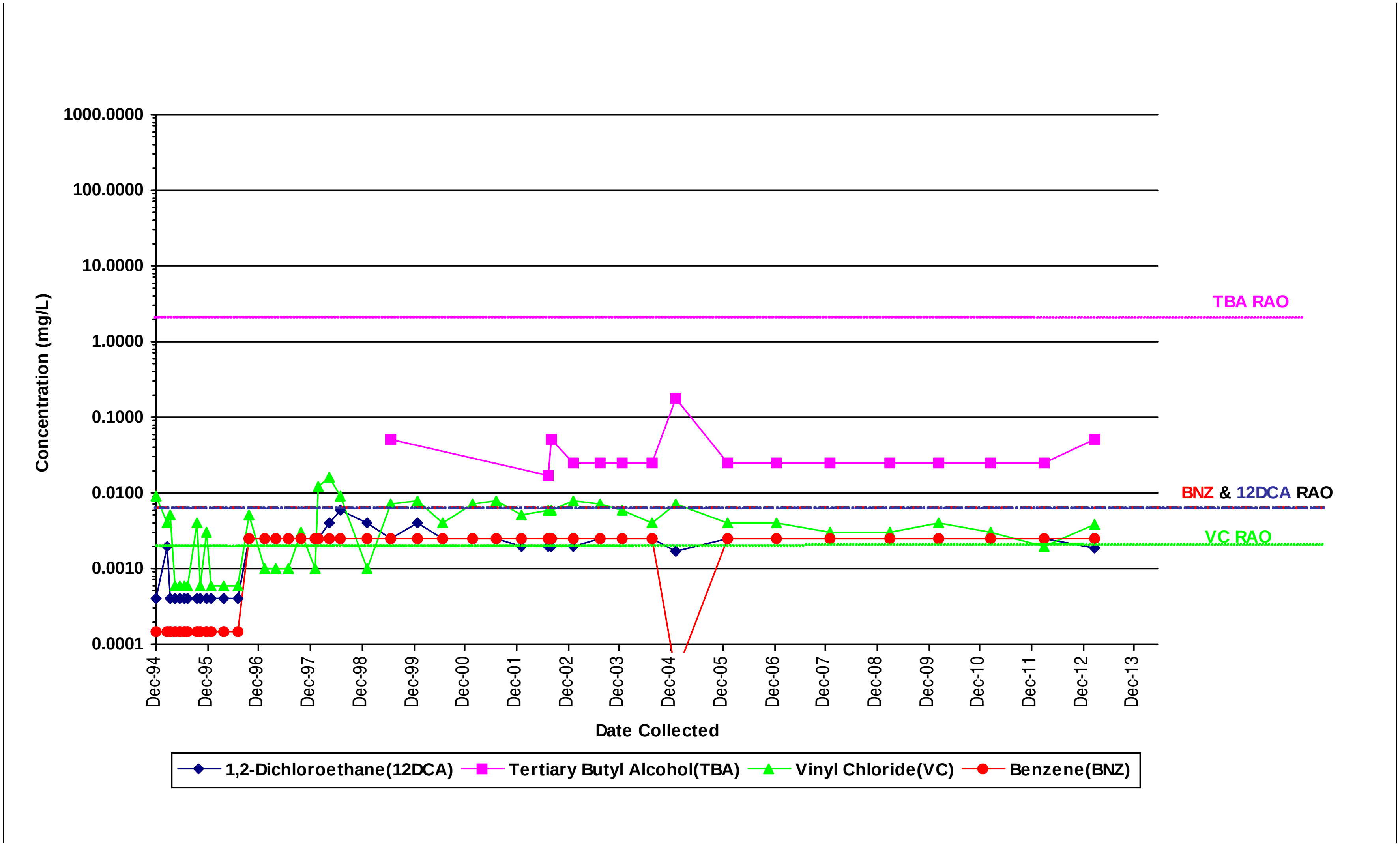



Not Detected results are graphed as 1/2 the laboratory reporting limit.

**WEST PLUME AREA**

**Unit Screened: INT**

## Well: INT-144




Not Detected results are graphed as 1/2 the laboratory reporting limit.

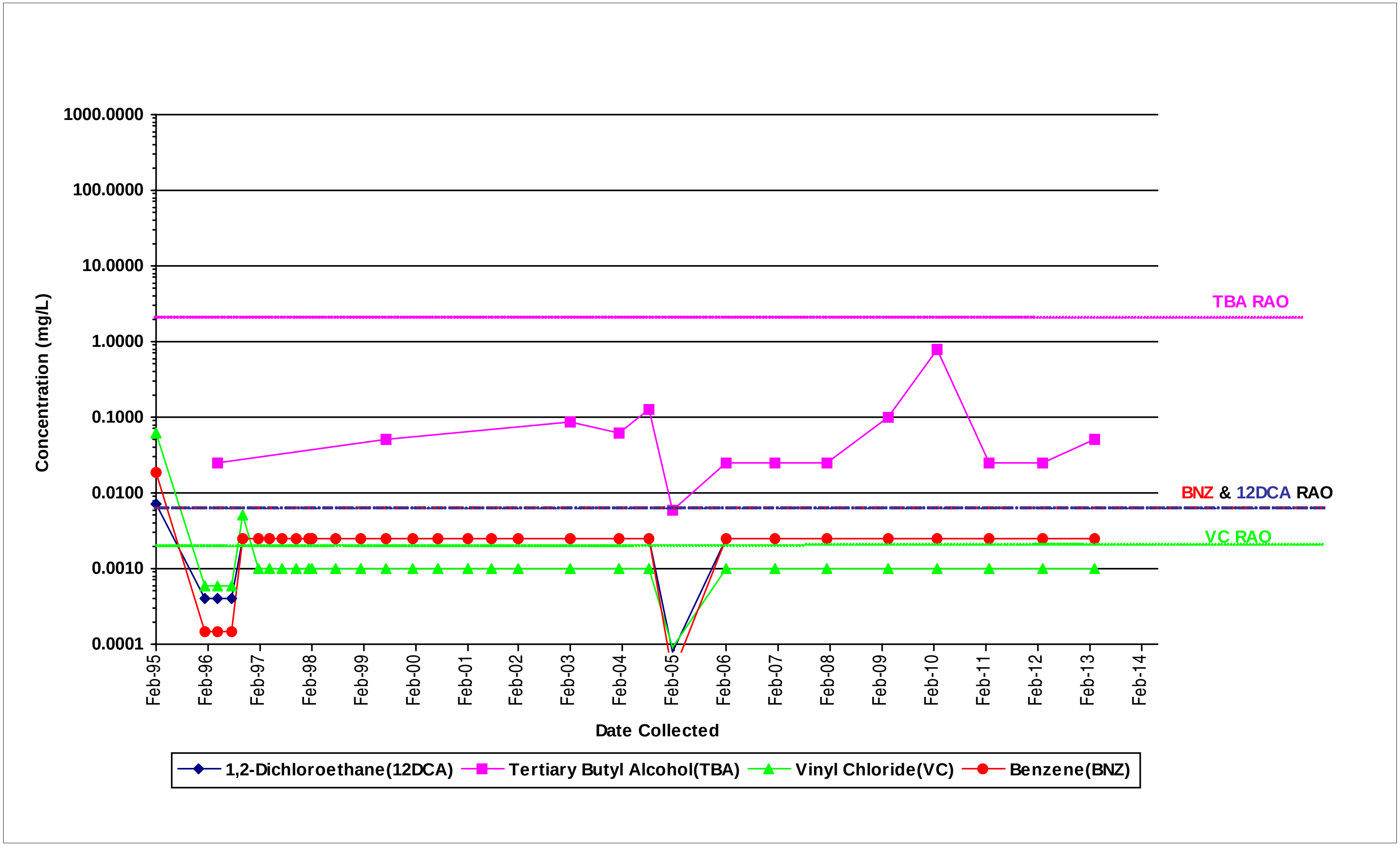
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: INT**

## Well: INT-214




Not Detected results are graphed as 1/2 the laboratory reporting limit.

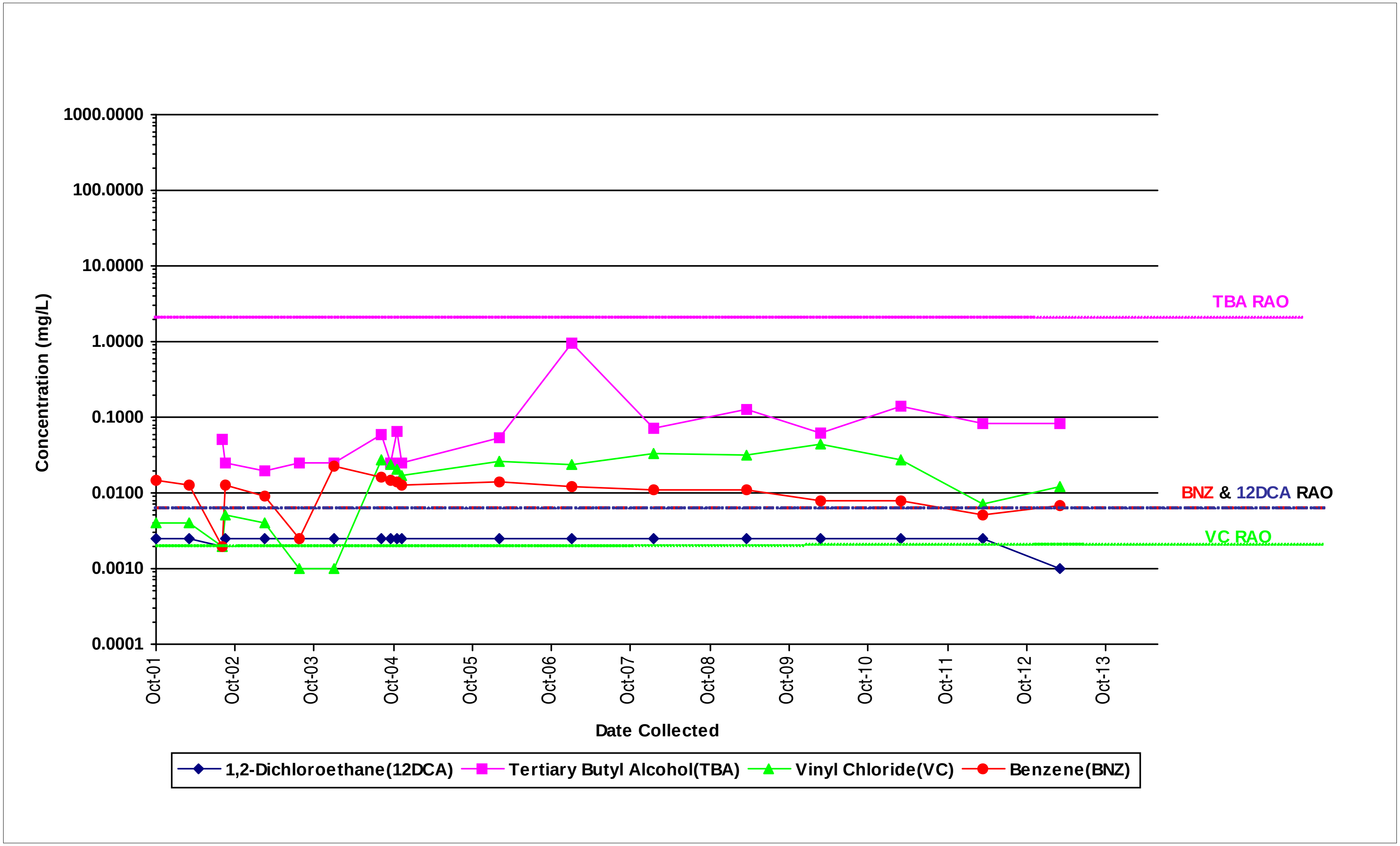
Ground Water Progress Graph

French Limited Superfund Site

**WEST PLUME AREA**

**Unit Screened: INT**

**Well: INT-253**




Not Detected results are graphed as 1/2 the laboratory reporting limit.